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A Summary of Current Program and
Preliminary Report of Progress

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GRAIN AND FORAGE RESEARCH

of the
United States Department of Agriculture
and cooperative agencies; + 2

Section A

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

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UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
December 31, 1963

ADVISORY COMMITTEES

The research program of the Department of Agriculture is reviewed annually by the following advisory committees:

1. Farm Resources Research
2. Utilization Research and Development
3. Human Nutrition and Consumer Use Research
4. Marketing Research and Service
5. Agricultural Economics Research
6. Forestry Research
7. Animal and Animal Products Research
8. Cotton and Tobacco Research
9. Grain and Forage Crops Research
10. Horticultural Crops Research
11. Oilseed, Peanut and Sugar Crops Research

ORGANIZATIONAL UNIT PROGRESS REPORTS

The source materials used by the advisory committees are of two types. First there are Organizational Unit Reports that cover the work of the Divisions or Services listed below. The number prefixes refer to advisory committees listed above that review all of the work of the respective Divisions or Services.

Agricultural Research Service (ARS)

- 1 - Soil and Water Conservation
- 2 - Utilization -- Eastern
- 2 - Utilization -- Northern
- 2 - Utilization -- Southern
- 2 - Utilization -- Western
- 3 - Human Nutrition
- 3 - Clothing and Housing
- 3 - Consumer and Food Economics
- 7 - Animal Husbandry
- 7 - Animal Disease and Parasite

Agricultural Marketing Service (AMS)

- 4 - Market Quality
- 4 - Transportation and Facilities

Economic Research Service (ERS)

- 4,5 - Marketing Economics
- 5 - Farm Production Economics
- 5 - Resource Development Economics
- 5 - Economic and Statistical Analysis
- 5 - Foreign Development and Trade Analysis
- 5 - Foreign Analysis Division

Other Services

- 1 - Soil Conservation Service (SCS)
- 4,5 - Farmer Cooperative Service (FCS)
- 4,5 - Statistical Reporting Service (SRS)
- 6 - Forest Service (FS)

Three organizational unit reports are not reviewed in entirety by any one committee. All of the information in them is included in the subject matter reports.

Agricultural Research Service (ARS)

Agricultural Engineering
Crops
Entomology

SUBJECT MATTER PROGRESS REPORTS

The second type of report brings together the U.S.D.A. program and progress for the following commodities and subjects:

- | | |
|--|--|
| 1 - Cross Commodity Research of
Agricultural Engineering, Crops,
and Entomology Research Divisions | 7 - Cross Species and Miscellaneous
Animal Research |
| 3 - Rural Dwellings | 8 - Cotton and Cottonseed |
| 6 - Forestry (Other than Forest
Service) | 8 - Tobacco |
| 7 - Beef Cattle | 9 - Grain and Forage Crops |
| 7 - Dairy | 10 - Citrus and Subtropical Fruit |
| 7 - Poultry | 10 - Deciduous Fruit and Tree Nut |
| 7 - Sheep and Wool | 10 - Potato |
| 7 - Swine | 10 - Vegetable |
| | 10 - Florist, Nursery and Shade Tree |
| | 11 - Oilseeds and Peanut |
| | 11 - Sugar |

A copy of any of the reports may be requested from W. C. Dachtler,
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of Agriculture, Washington, D. C. 20250

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INTRODUCTION

This report on grain and forage crops research covers work directly related to the production, processing, distribution and consumption of grain, rice, feed, forage and seed and their products. It does not include extensive cross-commodity work, much of which is basic in character, which contributes to the solution of not only grain and forage crop problems but also to the problems of other commodities. Progress on cross-commodity work is found in the organizations' unit reports of the several divisions.

This report is organized by "Problem Areas" which are shown in the table of contents. For each area there is a statement of (1) the problem, (2) the USDA program, (3) a summary of progress during the past year on USDA, and cooperative work, and (4) a list of publications resulting from USDA and cooperative work.

Research on grain and forage crop problems is supported by (1) Federal funds appropriated to the research agencies of the USDA, (2) Federal and State funds appropriated to the State Agricultural Experiment Stations, and (3) private funds for research carried on in private laboratories or for support of State station and USDA work.

Research by USDA

Farm research in the Agricultural Research Service comprises investigations on introduction, breeding and genetics, variety evaluation, culture, diseases, nematodes and weed control, insects, and crop handling and harvesting equipment and structures. This research is carried out in the Crops, Entomology, and Agricultural Engineering Research Divisions. It involves 345 professional man-years of scientific effort.

Nutrition, Consumer and Industrial Use Research in the Agricultural Research Service pertains to composition and nutritive value, physiological availability of nutrients and their effects, new and improved methods of preparation, preservation and care in homes, eating establishments and institutions, new and improved food, feed, and industrial products and the processes related to grains, rice, and forages. It is carried out in the following research divisions: Northern, Southern, and Western Utilization; Human Nutrition; and Consumer and Food Economics. The work involves 256.9 professional man-years of scientific effort.

Marketing and Economic research is carried out in four Services. Grain, rice, feed, forage, and seed research in the Agricultural Marketing Service deals with physical and biological aspects of assembly, packaging, transporting, and storing, and distribution. It is carried out by the Market Quality and Transportation and Facilities Research Divisions. Work in the Economic Research Service deals with marketing costs, margins, and efficiency; market potential; supply and demand; and outlook and situation. Consumer preference studies are carried out by the Statistical Reporting

Service. Research on cooperative marketing is conducted by the Farmer Cooperative Service. The grain and forage research in these Services involves 73.5 professional man-years of scientific effort.

Interrelationships Among Department, State and Private Research

A large part of the Department's research is cooperative with State Experiment Stations. Many Department employees are located at State stations and use laboratories and office space close to or furnished by the State. Cooperative work is jointly planned, frequently with representatives of the producers or industry affected participating. The nature of cooperation varies with each study. It is developed so as to fully utilize the personnel and other resources of the cooperators, which frequently includes resources contributed by the interested producers or industry. There is regular exchange of information between station and Department scientists to assure that the programs compliment each other and to eliminate unnecessary duplication.

Privately supported grain and forage crops research emphasizes the solution of specific production, processing, and marketing problems. Much of it utilizes the results of more basic work done by State Station and Department scientists. For example, private research is devoted to the synthesis and evaluation of chemicals as herbicides, fungicides, and insecticides, the development of new combinations of materials for use as fertilizers, product and process development, improvements in equipment for planting, cultivating, harvesting, handling, processing, drying and storing grains, forages and seeds. Private research in marketing and economics is largely concerned with studies of consumer preferences, market potential, promotion and market development.

The contributions of producers of grain and forage crops and of related industries to the work of State stations and the Department have been an important factor in the success of public research programs. Producers, processors, and distributors offer land, products, and facilities for the testing of equipment and practices used in the production and distribution of grain, rice, feed, forage, and seed and their products.

Examples of Recent Research Accomplishments by USDA and Cooperating Scientists

Interrelation of Tolerances in Corn to Stalk Rot, Corn Borer, and Certain Herbicides. A review of the currently available literature indicated the possibility of selecting inbred lines of corn differing widely in response to two triazine herbicides--atrazine and simazine. The literature suggested a relation between resistances to stalk rot, corn borer, and triazine herbicide based on the ability of a chemical complex in corn to impart resistance to fungi and insects and to break down triazine herbicides. Three inbred lines of corn highly resistant

to stalk rot and corn borer and 2 inbred lines with low resistance were evaluated for resistance to atrazine and simazine. The inbreds responded to the herbicides as anticipated. Those with high resistance to stalk rot and corn borer were highly resistant to atrazine and simazine whereas those with low resistance to stalk rot and corn borer were low. Inbreds with wide differential responses should provide excellent material for more detailed physiological studies of the basis of selective herbicidal action.

Hoja Blanca-Resistant Long-Grain Rice Varieties. When research on Hoja blanca rice virus was started in 1957, no resistant long-grain variety was available, but resistance was found in short- and medium-grain varieties. Breeding investigations were started that year in cooperation with the Arkansas, Louisiana, and Texas Agricultural Experiment Stations to develop resistant long-grain types by crossing commonly grown and experimental long-grain varieties with Hoja blanca-resistant short- and medium-grain varieties. Progenies were tested for reaction to Hoja blanca and in some cases two generations per year were grown in tests in Colombia and Mexico. This work was conducted under an informal arrangement with the Rockefeller Foundation, the Division of Agricultural Research in Colombia, and the National Institute of Agricultural Research in Mexico. Long-grain selections now available from this research are resistant to Hoja blanca and have the agronomic and cooking characteristics needed for adaptation to the southern rice area.

Stabilized Alfalfa Meal; A New Export Item. Department research on stabilization of important nutrients of dehydrated alfalfa is playing a vital role in the development of a new export market for this product. Dehydrated alfalfa meal is used primarily as a concentrated source of carotene (provitamin A), vitamin E, and xanthophylls (the pigments which cause the yellow color in egg yolks and in the skin and shanks of broilers). These alfalfa nutrients are rapidly lost by oxidation under ordinary storage conditions. U.S.D.A. research on stabilization of these sensitive nutrients has already led to the development of the antioxidant feed additive, ethoxyquin, which reduces losses to one-third that ordinarily suffered. Without its use, it would be impossible for U.S. producers to deliver a high potency product in Europe or Japan because of the prolonged "in transit" times required. Since ethoxyquin's acceptance by the Food and Drug Administration in 1958, exports of dehydrated alfalfa have risen from virtually none to 150,000 tons last year. This figure is expected to increase in the future. In the domestic market last year, ethoxyquin was used on over a million tons of dehydrated alfalfa meal and helped the alfalfa dehydration industry maintain healthy growth despite the pressure of stable synthetic competitive products.

Cereal xanthide paper made on pilot-plant scale. By use of the process developed by Department researchers, paper containing cereal xanthide has been successfully produced on a pilot-sized paper machine. The water-insoluble cereal xanthides are produced by treating flours, starches, or ground whole cereal grain with readily available, low-priced chemicals. Linerboard paper for corrugated paper boxes exhibited improved crush resistance under moist conditions, which is a major deficiency in conventional corrugated boxes. Bag paper containing 20 percent cereal xanthide exhibited superior wet and dry strength. Greaseproof paper containing 40 to 50 percent cereal xanthide showed improved properties over conventional greaseproof paper. Other applications are being developed. For example, wheat millfeed xanthide gives coarse, industrial paper with promising properties. Estimates indicate that the rapidly expanding paper products industry--now producing 37.5 million tons annually--could utilize cereal xanthides requiring over 100 million bushels of cereal grains per year.

Vitamin B₆ in cereal products determined by new method. An accurate method was developed for separating and measuring the three chemically related compounds of the nutritionally essential vitamin B₆--pyridoxine, pyridoxal, and pyridoxamine. This advance will make it possible to secure much needed information on vitamin B₆ components in food. Most whole grains and products from whole grains assayed contained 2 to 4 micrograms of vitamin B₆ per gram, whereas highly processed cereal products such as all-purpose flour, white bread, precooked rice, noodles, macaroni, and spaghetti generally contained less than 1 microgram.

A New and Novel Process Developed for Determining the Suitability of Artificially Dried Corn for Commercial Uses. Research engineers have developed a quick and inexpensive process--and a device for performing the process--that can detect damage to corn due to overheating during drying, as a replacement for time consuming and expensive laboratory processes. The new process involves a determination of changes in hygroscopic properties of corn as indicated by the increase in equilibrium relative humidity above the standard for corn of good quality (designated as the shift in equilibrium moisture content); changes which are directly related to corn quality. Commercial users can employ the new process in selecting corn that will meet their individual requirements for wet milling and other end uses, as well as for safe storage. Studies show the new process is 95 percent effective in detecting samples that had been dried at temperatures above 190° F. Development of this process represents a substantial "break-through" in providing a satisfactory measure of the suitability of corn for processing and storage and can effect savings to the industry amounting to many thousands of dollars annually.

Rapid Accurate Moisture Determination of Grain. A new method for measuring the moisture content of grain has been developed. A direct spectrophotometric measurement is made on a ground sample to indicate the moisture content to a precision of 0.1%. This is a fundamental method of measurement which may serve as a definition of moisture content. Technique has been applied only to wheat, wheat flour and soybeans, but it should be applicable to all grains and seeds.

I. FARM RESEARCH

BARLEY CULTURE BREEDING, DISEASES AND VARIETY EVALUATION Crops Research Division, ARS

Problem. Of the cereal crops, barley ranks fifth in the United States in acreage, production, and value of the crop. During the last 10 years the acreage planted to barley has increased approximately 25 percent to over 16 million acres, but was somewhat less in 1962. Barley is grown in 49 of the 50 states and is a major crop in 40 states, representing a wide variety of environmental conditions. Half of the crop is used as feed for livestock, 20 to 30 percent for malting, and 20 percent is exported. Barley is subject to yearly fluctuations in yield and quality due to factors such as climate, disease, lodging, winterkilling, shattering, drought injury, insect damage, and other factors because it is grown so widely. There is an increased need for work on genetics, cytology, breeding methods, pathology and physiology to strengthen the breeding of barleys to buffer the effects of the hazards mentioned. Studies on the important disease organisms, including viruses, host-parasite relationships at both physiologic and genetic level, nature of disease resistance, and host range of various parasites need strengthening. There is an increasing need for research on malting quality, for a more precise definition of quality and methods of evaluation. For all phases of breeding, we need to find a universal way by which individual genes can be identified with complete accuracy in the parents and in their progeny. The basic new concepts emerging from studies on DNA, the genetic code, transduction and other techniques; the newer methods of chromosome engineering, and the new advances with chemical mutagens need to be thoroughly studied and investigated for their possible use in applied barley breeding. The studies on the possibility of hybrid barley need to be intensified, as well as the role of genetics in the use of agricultural chemicals. Applied studies that need greater attention include the effects of environmental factors and cultural practices on yield and quality, and factors to reduce the yearly fluctuations in yield and quality.

PROGRAM

The Department has a continuing long-range program of both basic and applied research on barley improvement. In basic research the areas under investigation are genetics, cytogenetics, radiation genetics, pathology, virology, biochemistry, and physiology. Basic and/or applied research is carried on in cooperation with the following State Agricultural Experiment Stations: Arizona, California, Idaho, Michigan, Minnesota, Montana, Nebraska, North Carolina, North Dakota, South Dakota, Utah, and Wisconsin. A Federal National Barley and

Malt Laboratory is located at Madison, Wisconsin, and is operated in cooperation with the Wisconsin Agricultural Experiment Station. This laboratory conducts quality work on barley for both State and Federal programs. The world barley collection is maintained and distributed from Beltsville, Maryland. Federal personnel supervise four spring and three winter uniform nurseries.

The Federal scientific effort devoted to research on barley totals 19.2 professional man-years, of which 8.1 is for breeding and genetics, 5.0 for diseases, 5.0 for variety quality evaluation, and 1.1 for culture (physiology).

Additional research on barley is carried out under five Public Law 480 projects located in three foreign countries, namely: Poland (2), Egypt (1), and Israel (2). This research includes studies on the disease affecting barley, namely, rusts, smut, net blotch, mildew and scald, and a search for varieties resistant to these diseases; also studies on the origin of barley. The effect of genetic and environmental factors on the feeding value of barley proteins is being studied by Montana State College under a contract involving an estimated six-tenths professional man-year.

PROGRESS

A. Breeding and Genetics

1. Composite Cross XXI. This composite cross was made by using the spring varieties in the World Collection as male parents on a series of 50 male sterile stocks. It is estimated that approximately 5,000 to 5,500 crosses were made and these have a chance to recombine after the F_2 because of the presence of the male sterile gene. This cross has large inherent potentials for many environments and to date 37 seed lots have been distributed to 21 foreign countries and 24 lots to 17 states from Alaska to Florida.

2. Male Sterile Genes. At Bozeman, Montana and Aberdeen, Idaho, diallel test crosses involving the male sterility character show the existence of numerous genes, and that these are nearly all found at different loci in the genome. The number of different loci identified to date is 15 and an additional 15-20 genes are awaiting tests. This multiplicity of loci is encouraging from the standpoint of finding the required ms-ddt linkage for hybrid barley. In addition, it is of both theoretical and practical interest to find the reason for this multiplicity of loci for this character as compared with the singleness for other characters. In cases where gene action is additive, a breeding technique by which genes of economic worth could be added at will, would be a new and important means for improving our crop plants.

3. Pollen Source Homozygous for Recessive Lethal Genes. A method has been devised and tested whereby a pollen source can be produced where 100 percent of the pollen grains are homozygous for a recessive lethal gene. This method employs a balanced tertiary trisomic to attain this result. In this type of trisomic the lethal gene used is placed in the genome in a manner such that through linkage, gamete abortion, and transmission barriers through the male, the only effective pollen is that which is homozygous for the lethal gene used. This technique also provides a means for automatically maintaining lines for sterile or lethal mutants.

4. Breeding Improvements. At Madison, Wisconsin, progress is reported in breeding for stiffness of straw by using as parental sources, Belowmee (a variety from Afghanistan) and Joton (a mutant variety from radiation). The excellent loose smut resistance in Trebi has been combined with malting quality for the first time. A close linkage was found for the genes controlling orange lemma (o) and unicum (uc₂) on chromosome 6, and the gene order and linkage values for three genes on chromosome 1 are as follows: t (2) un (13) wx, where t = stem rust resistance, un = loose smut resistance, and wx = waxy starch.

5. Inheritance of growth habit and winterhardiness. From 38 crosses involving 12 spring and 5 winter varieties, it was determined that spring growth habit may be conditioned either by a recessive gene pair, or a dominant gene pair.

Thirteen of the above spring x winter crosses were studied for winter survival in F₃ lines under field conditions. A definite association was established between winter growth habit and high winter survival but this association was not complete since hardy spring lines were also isolated.

There was no relation between winter survival and the factors for spike density and number of rows on the spike, but an association was evident between survival and the factors for awn barbing and rachilla hair length.

6. World Collection. During 1962 the World Collection of barley received 629 new accessions from a total of 30 countries. The World Collection of barley now contains 8,957 entries. This is an increase of approximately 7 percent in number of items in the barley collection.

During the past year, 45,863 seed packets from the barley collection were prepared and shipped to barley workers. Barley investigators in 18 foreign countries requested and received 22,741 samples during the past year, whereas workers from 30 states received 23,122 samples.

7. New Varieties (Winter). Four new winter barley varieties were released to certified and/or foundation seed growers. The variety Catskill was developed and released by the Cornell Agricultural Experiment Station. It has an awnleted spike and is superior to Wong in winterhardiness, test weight, strength of straw and scald resistance. It matures somewhat later than Wong. Besbar, another awnleted variety similar to Wong, was developed and released by Eastern States Farmers' Exchange, West Springfield, Massachusetts. Its principal advantages over Wong are: greater winterhardiness, higher yield, and more tolerance to scald. A third awnleted variety, Pennrad, was developed and released by the Pennsylvania Agricultural Experiment Station. Pennrad is more winterhardy than Wong and is highly resistant to scald. A bearded variety, Dover, was developed and released by the Ontario Agricultural College as a possible replacement for Hudson. Dover is similar to Hudson in winterhardiness but has stronger straw, higher test weight and threshes more readily than Hudson.

8. New Varieties (Spring). Two new spring varieties were released this year. Vale, developed at the Utah Agricultural Experiment Station and released by the Oregon Agricultural Experiment Station is especially well suited to the irrigated valleys of eastern Oregon and is recommended for those areas. The advantages of Vale are its stiff straw, higher yield, test weight, and resistance to mildew. Grande is a new feed barley released in California where it is intended as a replacement for Winter Tennessee. Grande originated as a selection from Composite Cross II, and its chief advantages are a higher yield, superior rolling characteristics when the grain is prepared for feed, more tolerance to leaf diseases than Winter Tennessee, and larger seeds. It is similar to other California varieties in maturity and other plant characters.

9. Distribution and Association of Botanical Characters in a World Population of Barley Varieties. From a comprehensive analysis of 37 spike and kernel characters, the following major conclusions can be stated: The distribution of characters within the world barley population is not at random. The barleys from different countries and world areas are different. Certain characters have worldwide distribution; others occur in limited areas. Many potentially possible character combinations do not occur in this world population, indicating they may be less fit to survive in evolution. Evolution in barley through hybridization and mutation has occurred throughout the world and at different rates in different places. This study has added to our understanding of the genetics and evolution of barley, and thus, it serves as a basic background for planning research and improvement programs and for selective plant exploration.

B. Diseases

1. Stripe Mosaic. Techniques have been improved for concentrating and verifying the barley stripe mosaic virus. By use of the liquid-liquid phase separation method, the concentration of the virus was increased one hundred times with no loss in infectivity. By combining the liquid-liquid phase with a cross linked dextran column, it was possible to concentrate the virus more than one hundred times. Tests on thermoinactivation of the barley stripe mosaic virus in barley seed have shown that virus-infected seed dried to 2.7 percent moisture and then subjected to temperatures of up to 120°C. were still viable and the virus was not inactivated. In a study on pollen and embryo transmission of the barley stripe mosaic virus, it was found that there was 17 percent transmission through the pollen, 46 percent transmission through the embryo, and 58 percent when both parents were infected.

Electrophoretic mobility rates were shown to be effective in characterizing the plant viruses, tobacco mosaic viruses (TMV), barley stripe mosaic virus (BSMV), brome mosaic virus (BMV), and southern bean mosaic virus (SBMV). The rate of mobility of these viruses was in the order listed.

2. Pathogenicity of Helminthosporium. Progeny from crosses of the fungi Cochliobolus carbonum and Cochliobolus victoriae have been used to study the inheritance of various characteristics of those fungi. Some genes for pathogenicity were found to be inherited independently and others were linked. The major gene for compatability was inherited independently from the genes for pathogenicity which were studied. Certain of the progeny were pathogenic on hosts resistant to both the parent isolates. The results indicate that genetic recombinations within and between the fungal species play an important role in the evolution of pathogenicity of those fungi. Isolates of Helminthosporium sorokinianum obtained from Paraguay, Alaska, Canada, and several locations in the United States were tested for pathogenicity and compatability. The isolates were found to be essentially similar in pathogenicity on species of 21 genera of the Gramineae and the two compatability groups were equally represented among the isolates.

3. Host-Pathogen Genetics. Additional information regarding the pathogenicity of the fungus Erysiphe graminis f. sp. hordei which causes the powdery mildew disease has been obtained. The relationship of eight genes conditioning pathogenicity has been determined. It has been shown how information regarding genes for resistance in the host was obtained in six months from studying genes in the pathogen, whereas over two years were required to obtain similar information by studying crosses of the host. The effect of genes conditioning the reaction of commercial varieties on changes in pathogenicity of the fungus was shown.

4. New Sources for Resistance. New sources for resistance to diseases in cultivated barley and Hordeum species have been obtained through Public Law 480 projects A10-CR-1 in Israel and F4-CR-1 in Egypt. Hordeum species resistant to powdery mildew, leaf rust, and net blotch have been received from Israel. Varieties resistant to the net blotch fungus in Egypt have been obtained. This material is being evaluated with strains of the various fungi in North America.

5. The relation of meteorology to barley yellow dwarf epidemics. In the north central region investigations on factors conducive to epidemics of the virus disease barley yellow dwarf were started in 1962. Examination of trap plants of oats, barley, and wheat exposed during the period June 18 to July 3 showed no aphids, the vectors of the virus. The trap plants were probably exposed too late in the season. The United States Weather Bureau is cooperating in this study by providing wind trajectories and pressure patterns for the area from Texas to Canada as a basis for interpreting dispersal of aphids.

C. Varietal Evaluation (Quality)

1. Varieties from State and Federal Breeding Programs. As in previous years, a large number of barley varieties and promising selections from breeding programs were evaluated for quality. The laboratory located at Madison, Wisconsin, serves both Federal and State breeders across the nation in this quality work. The results are made available as quickly as obtained. In addition to variety evaluation, the laboratory also determines the effect of fertilizers, herbicides, and other cultural practices on malting quality. A brief description of the kind of material tested follows: (1) Varieties from 4 uniform nurseries which cover most of the barley areas from which malting barley is bought, (2) individual sets of varieties from 11 states, ranging from 8 to 180 in number were evaluated this year, and (3) winter barley varieties from 4 states where breeding work is underway to produce varieties with malting quality. The most promising selections from this overall testing program were also evaluated for brewing quality.

2. Effect of Chemical Additives on Quality. Further tests with gibberellic acid indicate that a maximum favorable response is obtained with 20 p.p.m. based on the dry weight of barley. The low enzymatic activity of Atlas and Betzes barley was markedly stimulated by this treatment. When 3-amino-1,2,4-triazole was used instead of gibberellic acid the effect was similar although adverse effects were noted giving dark-colored wort and beer and an objectionable odor. Germination was inhibited with 2-chloroethyltrimethyl ammonium chloride, potassium bromate and 2-4-dichlorophenoxy acetic acid.

3. Effect of cultural practices on quality. Forced lodging of three barley varieties increased the nitrogen content of the kernel and reduced kernel weight. The expected adverse changes in quality correlated with nitrogen content and kernel size were realized in this test. The variety Traill was injured less by lodging than Kindred or Wis. X914-4. When increasing seeding rates are combined with increasing seeding rates within reasonable limits, malting quality is affected very little.

4. Amino Acids. A modification to the amino acid analyzer now permits the simultaneous recording of the amino acids and the nucleic acids in the same run. This modification will permit the rapid accumulation of data on these constituents, so important in the metabolic and physiologic processes of barley. It was shown that the redrying of a malt at a higher temperature in preparation for its use in brewing did not alter the free amino acid constituents. In air classified samples of malt (prepared in a manner similar to that used for wheat flour) it was discovered that a greater amount of free amino acids were found in those fractions rich in husk and germ tissue. Comparisons of the various free amino acids in the germ and endosperm of barley seeds showed that the embryo is richer in these acids than the endosperm and notably so for two of the amino acids. All of the glutamine and nearly half of the arginine are located in the embryo. Proline and asparagine also are relatively abundant in the embryo.

5. Electrophoretic Separation of Barley Proteins. By use of electrophoresis on polyacrylamide gels it was possible to resolve the protein in barley seed into 13 to 18 components. The proteins from malts of these same barleys were less clearly resolved. This method is promising and merits further study.

6. Emetic Principle in Scabby Barley. The emetic compound found in scabby barley and which greatly impairs its feeding value, has now been resolved into two fractions. One, a neutral compound, has chemical properties similar to the emetic previously reported from infected corn and from artificial cultures of Fusarium moniliforme No. 111. The other fraction is a weak acid and may be produced in culture media as well as in scabbed barley.

7. Brewing Tests. Preliminary malting and brewing tests of hybrid barley seed indicated no heterotic effect for the various factors measured. No general conclusions can be drawn from these tests as they represent only a limited set (4) of hybrids from one location.

D. Culture (Physiology)

1. Freezing Processes in Winterhardiness. Two major categories of freezing processes have been found: (1) Equilibrium freezing processes in which the amount of liquid remaining in spaces between

living protoplasts is exponentially related to temperature as freezing progresses. The equilibrium processes are reversible. Cells contract in equilibrium with the formation of ice in the spaces between protoplasts. Equilibrium processes occur in tissues where the intercellular liquid is closely associated with living protoplasts as films in the cell walls. Injury occurs when physical stresses in the protoplast exceed protoplasmic stability, and (2) the other major category consists of non-equilibrium freezing processes. These processes are not in equilibrium with temperature and they are not reversible. Ice masses form explosively at the freezing point of liquid in xylem vessels or other spaces where the liquid is not closely associated with hardy living protoplasts. The sudden formation of large crystals will destroy critical regions of the plant.

2. Physiological Effect of DDT on Barley. In susceptible barley plants injury from DDT occurs very soon after treatment, as evidenced by the decrease in chlorophyll and transpiration rate. The primary injury is confined to the treated area. Later, secondary effects occur which aid in creating a phytocidal effect. The biochemical nature of the injury has not been determined but it is known that DDT enters the plant tissue; that it is not translocated; and that degradation of DDT to DDE in resistant barley plants does not occur as is the case with some resistant insects.

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CORN AND SORGHUM CULTURE, BREEDING
DISEASES, AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. The combined production of corn and sorghum totals approximately 4 billion bushels annually and constitutes roughly eighty percent of our feed grain. The rapid expansion and near self-sufficiency of the hybrid seed industry requires an extensive reorientation of the current programs to give increased emphasis to basic research in genetics, physiology, and pathology. Some progress has already been made in giving greater emphasis to such needed research. Corn and sorghum production are dependent upon the utilization of hybrid vigor but no adequate genetic explanation of this phenomenon is currently available. In addition to basic research on this topic, additional information is needed on the relative efficiency of different breeding systems and the basis and mode of inheritance of disease and insect resistance. Increased efforts are needed in genetics and physiology to provide information basic to improvements in the nutritional and industrial qualities of the grain. Work is needed on mineral nutrition and the patterns of synthesis of protein, oil, and carbohydrates. More work is needed in pathology to determine the basis for resistance and the capabilities of disease organisms to become infectious on currently resistant types and to explore the whole host-parasite interaction system.

PROGRAM

The Department has a continuing long-term program involving geneticists, physiologists, pathologists, and agronomists engaged in basic and applied studies relating to the improvement of corn and sorghum. Corn research is conducted at Beltsville, Maryland; Charleston, South Carolina; and in cooperation with State Experiment Stations at the following locations: Tifton, Georgia; Urbana, Illinois; Lafayette, Indiana; Ames, Iowa; State College, Mississippi; Columbia, Missouri; Raleigh, North Carolina; Wooster, Ohio; Brookings, South Dakota; Knoxville, Tennessee, and Madison, Wisconsin. Sorghum research is cooperative with State Experiment Stations at Manhattan and Hays, Kansas; Lincoln, Nebraska; Stillwater, Oklahoma; Brookings, South Dakota and Chillicothe and College Station, Texas.

Ten PL 480 projects dealing with corn or sorghum are now in operation. These are: S3-CR-37 "Tropical cultivated plants, their evaluation and use as breeding material: Evaluation of corn and beans native to Central and South America as sources of germplasm for use in breeding programs in the U.S."; A7-CR-20 "Genetical effects of natural radiation from the Monazite Sands of Kerela"; A7-CR-72 "Research on maize diseases with special reference to Erwinia caratovora var zea"; A7-CR-73 "Response of various germplasm sources to agronomic practices"; A18-CR-2 "Fungicidal control of downy mildew of corn and the resistance of corn varieties, hybrids, and inbred lines to Downy Mildew"; E25-CR-1 "Factors affecting the frequency of monoploid seedlings in maize and their subsequent diploidization"; E30-CR-3 "Collection, classification, evaluation and preservation of domestic maize germplasm in Yugoslavia"; A7-CR-69 "Storage, maintenance and distribution of millets germplasm"; A7-CR-70 "Cataloging and classifying genetic stocks of sorghum"; A7-CR-19 "Carbohydrate metabolism in the tapioca plant, manihot utilissima."

The Federal research effort devoted to corn and sorghum totals 31.5 professional man-years. Of this number 23.5 is devoted to breeding and genetics, 5 to diseases and 3.0 to culture and physiology.

PROGRESS

A. Breeding and Genetics

1. Corn Genetics. Basic genetic studies are under way at Columbia, Missouri; Ames, Iowa; Raleigh, North Carolina and Beltsville, Maryland. These studies have as their objective a more complete understanding of the principles which underlie the improvement of corn. Such principles have utility for other plants and animals of economic interest. Current studies involve three rather distinct fields; classical genetics and cytogenetics, population genetics and biochemical genetics. Population genetic studies are underway at Ames, Iowa; Raleigh, North Carolina and Beltsville, Maryland.

a. Chromosome Pairing. The work on classical genetics and cytogenetics is concentrated at Columbia, Missouri. The cytological investigations deal primarily with the effects of various types of chromosome aberrations on chromosome pairing. Studies on preferential pairing involving trisomics (plants having one chromosome type in triplicate) with 2 standard and 1 exotic chromosome have indicated that non-random pairing is quite common. This is true whether the additional chromosome is normal but from an exotic source or involves structural modifications arising from irradiation.

b. Gene Conversion. Studies are being continued on a special case in which a particular gene, B^1 , has the capacity to convert or transform associated alleles (B) to a type like itself. This unusual condition appears to arise by a mutation like process and the modified form (B^1) appears to be associated with, if not actually, a part of a chromosome. Many characters have been found in recent years which exhibit this type of aberrant behavior but a satisfactory explanation is still to be devised.

c. Gene Duplication. The use of overlapping translocations permits the isolation of types having short segments of a chromosome in duplicate. Duplications are being sought for the genes Y, Su, wx and Ae. Preliminary tests suggest that such duplications have been obtained but further verification is necessary. The genes mentioned are of interest because of special nutritional or industrial properties.

d. Breeding potential of open-pollinated varieties. Studies were conducted at Beltsville, Maryland on the problem of differing breeding potential of open-pollinated varieties. The variety Midland has been a good source of inbred lines whereas no usable lines have ever been developed from the variety Hickory King. The varietal hybrids exhibited considerable heterosis when measured from the mid-parental value. The hybrids, however, were not higher yielding than the best of the intra-Midland combinations. Estimates of genetic variability were essentially similar. The poor breeding potential of Hickory King appears to be related to its poor performance as a variety.

e. Gene action in heterosis. Theoretical studies were continued at Ames, Iowa on comparisons of single, three-way and double-crosses designed to provide evidence on the type of gene action involved in heterosis. Preliminary results suggest that gene action in highly selected lines may be quite different than in a series of unselected lines from the same original population.

f. Biochemical genetics of carotenoid pigments in grain. A series of genes have been identified which affect carotenoid pigments in the grain. Biochemical studies are underway to establish the effects of these genes individually on biosynthesis. In one strain carotene synthesis is interrupted between zeta-carotene and alpha-carotene. Thus alpha and beta-carotene are completely lacking. There is, however, no corresponding qualitative effect on the xanthophylls. This suggests that biosynthesis in corn does not follow the sequence postulated for some other plant species.

2. Dent Corn Breeding.

a. Inbred lines released. Pollen restoring versions of the inbred lines B8, B10, C103, N6, Oh43 and Oh51A have been developed and were released in 1962.

One new inbred line, Oh45B, was released from the cooperative program at Wooster, Ohio. Six new hybrids developed in this program will be available for commercial production in 1963. The line Oh45B is one of the parents of four of these six hybrids.

Three new white lines were released from the cooperative program conducted at Columbia, Missouri. These were Mo.14W, Mo.15W and Mo.16W. Mo.15W and Mo.16W are used in special hybrids developed for use by the cob-pipe industry.

b. Inheritance of corn borer resistance. Chromosomal translocations have been used to identify the chromosome arms carrying genes for resistance to corn borer leaf-feeding. The inbred line CI.31A has a gene or genes for resistance on the short arm of chromosome 2, on both arms of chromosome 4 and possibly on the long arm of 10.

c. Performance of dwarf and normal hybrids. Studies were continued at the Mississippi Station on the relative yielding ability of dwarf and normal hybrids. The highest yielding hybrid, of the group tested, was a dwarf single-cross, T204 x GT112. The two height groups, however, did not differ significantly in average performance.

d. High xanthophyll corn. Work on the development of high xanthophyll corns for the poultry broiler industry is being continued at Mississippi in cooperation with the Northern Utilization Research and Development Laboratory. Existing corn inbred lines and hybrids exhibit a wide range in xanthophyll content. A few lines derived from crosses of native and exotic types have xanthophyll concentrations in excess of 60 p.p.m. Hybrids having at least three of the parental lines high in xanthophyll were evaluated for yield in 1962. Several of this group were equal to the standard check in yield. Therefore the development of high-yielding, high-xanthophyll hybrids appears to be entirely feasible.

e. High amylose corn. Methods are now available for the determination of amylose percentage on a single kernel basis. Preliminary results obtained at the Missouri Agricultural Experiment Station suggest that the mean amylose percentage from single kernel analysis is somewhat higher than that obtained by bulk analyses, using the standard method. The single kernels used in this study can be grown and will be used to determine parent-progeny relationships.

f. Earworm resistance. Mass selection for earworm resistance was begun at Columbia, Missouri in 1956 in two synthetic varieties. Five cycles of selection have now been completed. Significant progress has been made in both synthetics. In addition a number of inbred lines have been developed possessing resistance to the earworm. Hybrids involving these lines have been evaluated for earworm resistance at both Columbia, Missouri and State College, Mississippi. Several of the hybrids exhibited greater resistance than the resistant check, Dixie 18.

In cooperation with the Entomology Research Division studies were continued at Mississippi on the larval feeding habits of the corn earworm. Resistance to earworm damage is in part morphological and involves such aspects as length of husk extension beyond the ear tip, the diameter of the silk channel and the number and growth rate of the silks. Biochemical differences among the silks also appear to be involved. Preliminary data suggest a relationship between earworm susceptibility and the reducing sugar content of the silk.

3. Sorghum Genetics. Genetic and breeding studies are underway at each of the locations where cooperative work is in progress. Cytogenetic studies are concentrated at Lincoln, Nebraska and College Station, Texas. Studies on disease resistance at Manhattan, Kansas and College Station, Texas and the genetics of other characteristics at Chillicothe, Texas; Ft. Hays, Kansas; Lincoln, Nebraska and Stillwater, Oklahoma.

a. Chromosome marker stocks. Extensive cytogenetic studies are underway at College Station, Texas and Lincoln, Nebraska on the progeny of haploids (one chromosome set per plant) and triploids (three complete chromosome sets per plant) with the objective of isolating suitable chromosomal marker stocks. In the progeny of 26 haploids, 386 plants were diploids, 5 were trisomics, and 1 was haploid. No monosomic plants were found. Haploids therefore do not appear to be a useful source for aneuploid cytological stocks.

In contrast progeny from 1 triploid, 403, produced 17 trisomes, 1 double trisomic and additional plants which are probably trisomic. Triploids occur in normal populations with a frequency of approximately 1 per 3000 plants.

b. Genetic basis of heterosis. Estimates of general and specific combining ability provide some evidence on the type of gene action involved in heterosis. 190 sorghum hybrids were studied at Lincoln, Nebraska. Both additive and non-additive gene effects were found to be of importance for yield, seed size, and most of the other traits studied. Additive effects, however, were numerically the greater and were also more stable over environments. Crosses with as few as four testers were found to provide an adequate basis for estimating average hybrid performance.

4. Sorghum Breeding.

a. Comparison of single, 3-way and double-cross hybrids. The hybrid sorghum seed of commerce represents single-cross combinations. The use of 3-way hybrids may have some advantage because of possible reduction in seed production costs. Comparative tests of single, three-way and double-cross hybrids were conducted at the Ft. Hays, Kansas station in 1961 and 1962. Both three-way and double-cross yields were significantly greater than those of single-crosses. The yield of three-way crosses appeared to be more stable over seasons than either of the other hybrid types.

b. Effects of dwarfing genes. The dwarfing genes Dw₁, Dw₂ Dw₃ and Dw₄ have been reported to influence only internode elongation. Recent studies in Kansas and Texas suggest that leaf area and yield may also be affected. These findings are substantiated by the lower yields of 4-dwarf lines as compared with their 3-dwarf counterparts. In general the yields of 4-dwarf have been inferior to the yields of similar 3-dwarf hybrids.

c. New hybrids released. Four new hybrids were released from the Texas Station. These are RS 616, RS 621, RS 622 and RS 623. Each of these is 3 x 4 dwarf combination. Seed was also released of two grain grass sorghums, SA 3054 and SA 3056.

Parental seed has been distributed from the Nebraska Station for the commercial production of seed of 6 additional hybrids. The numbers and pedigrees of these hybrids are as follows:

<u>Number</u>	<u>Exp. Number</u>	<u>Pedigree</u>
RS 619	N 79	Martin x Plainsman-Midland 4917
RS 624	N 78	Combine Kafir 60 x Plainsman-Midland 4917
RS 625	62CS002	Martin x Tx414
RS 626	62CS001	Combine Kafir 60 x Tx414
RS 640	N 80	Wheatland x Plainsman-Midland 4917

B. Diseases

1. Corn Diseases

a. Helminthosporium. Research is underway at Raleigh, North Carolina on intra- and inter-specific hybrids involving several species of Helminthosporium. These studies have as their objective a clarification of the importance of hybridization and recombination on the development of new and more virulent pathogenic forms. The results to date may be summarized as follows:

- (1) Studies with intra-specific hybrids of H. sativum indicate that pathogenicity to specific hosts is conditioned by a single gene or gene system.
- (2) Interspecific hybrids between H. carthagenum and H. victoriae indicate genes for pathogenicity may be inherited either independently or linked.
- (3) Certain interspecific hybrid progeny were pathogenic to hosts resistant to both parental isolates, demonstrating increased pathogenic potential from hybridization between species.
- (4) Genetic recombination can produce strains of the fungus with greater pathogenicity than that associated with the conidial populations.
- (5) Strains of H. victoriae were shown by bioassay to differ in toxin producing potential. Variation in toxin production is quantitative and controlled by many genes. These studies constitute the first demonstration of the genetic control of toxin production in fungi.

b. Rust. The identification of sources of resistance to Puccinia polysora was continued at Beltsville, Md. Preliminary data on inheritance indicates that several genes are involved some of which condition resistance in the dominant and others in the recessive state. The development of isogenic lines, to facilitate further testing, is well under way.

A new inbred line Bl⁴A has been developed at Ames, Iowa which possesses resistance to all of the commonly occurring races of corn leaf rust, Puccinia sorghi. This line and its rust susceptible counterpart, Bl⁴, were compared in single-cross yield trials under natural and rust epiphytotic conditions. Under natural conditions the means of the two series of crosses were similar. Under conditions of heavy rust infection the resistant hybrids produced yield increases of 21 percent.

c. Stalk rots. Comparative studies were conducted at Lafayette, Indiana with resistant and susceptible single-crosses using 4 methods of inoculation and three stalk rotting pathogens, Diplodia maydis, Gibberella zeae and Fusarium moniliforme. The differences among methods of inoculation and strains within the pathogen were small as compared to the differences between hosts.

Diplodia maydis is one of the important pathogens involved in stalk rot of corn. Experiments conducted at Madison, Wisconsin suggest that there are important differences in pathogenicity among strains. These differences appear not to be related to geographical origin since virulent and avirulent cultures were obtained from each State.

Spore load of the inoculum appeared to affect the severity of the disease symptoms. Variations in pathogenicity, however, cannot be entirely accounted for by variations in amount of spore formation.

Preliminary observations made at Lafayette, Indiana on the relationship of boron and zinc fertilization to stalk rot showed a slight trend toward less stalk rot where either one or both elements had been applied. The effect, however, was not marked and genetic resistance of the host was far more effective in reducing stalk rot than the soil amendments. Observations made on the relationship of soil insecticides to incidence of stalk rot failed to indicate any reduction in amount of stalk rot where dieldrin was applied to soil to control northern and southern corn root worm.

d. Ear rot. A corn ear rot caused by Hormodendrum cladosporoides was generally distributed throughout southern Wisconsin in 1962. In some fields at least a third of the ears were infected with a resulting loss in yield. This disease has been reported previously for cribbed corn put into storage at a high moisture content. Artificial inoculation studies are planned for 1963 to search for possible sources of resistance.

e. Downy mildew. Studies on control of downy mildew of corn conducted in the Philippines under a PL-480 project, have indicated that spraying corn with chemicals can control the disease to a limited degree, and that resistant lines of corn are available which can be used in breeding programs.

2. Sorghum Diseases. It has been estimated that charcoal rot caused a loss of approximately 500,000 bushels in southern Kansas in 1962. Head smut was more prevalent than in previous years. Ten to 25 percent of smutted plants were not uncommon in irrigated fields of western Kansas.

a. Head smut. Artificial inoculation techniques have been devised for evaluating resistance to head smut. With this technique susceptible varieties may exhibit 70 to 75 percent of smutted plants. The old varieties Early Hegari, Spur Feterita and Double-dwarf White Feterita are highly resistant or immune.

b. Charcoal rot. The evaluation of resistance to charcoal rot has not proven feasible under uncontrolled field conditions. Evaluations have been possible in the greenhouse. All plants appear to be highly resistant prior to blooming. After blooming inoculated susceptible plants develop typical rotting symptoms very rapidly if subjected to temperature and moisture stress. The possibility of field inoculations in Arizona will be investigated. In this State temperatures are favorable for development of the disease and water stress can be initiated at any time through control of irrigation water.

c. Milo disease. A laboratory technique has been devised for screening seedlings for resistance to Periconia circinata at College Station, Texas. This organism causes a very destructive disease of milo and milo derivatives. The organism is cultured in liquid media and the seedlings exposed to the dilute filtrate. Susceptible seedlings die in about 6 days while resistant seedlings are not seriously affected. Resistance appears to be simply inherited. The mutation rate from susceptibility to resistance is of the order of 1 per 4-5000 gametes.

d. Seedling blight. A seedling disease has been prevalent in Nebraska for the past 6 years. In some years the seedlings are killed and in other years growth is retarded. Good control was obtained by fumigating the soil with 1 pound of methyl bromide per 50 square feet. Nematode counts were sufficiently high to suggest that they may contribute to the problem.

C. Culture and Physiology.

1. Corn.

a. Protein metabolism. Three ribonucleases have been isolated from germinating corn seedlings. Ribonuclease A, which is found in the scutellum and endosperm, has been highly purified and appears to be similar to the Ribonucleases isolated from other plants. Ribonucleases B and C can be isolated most easily by precipitating with the cellular particulate material with subsequent separation from the particles. It appears that Ribonuclease A is a degradative enzyme but the specific roles of Ribonucleases B and C remain to be clarified.

b. Date of planting and Southwestern Corn Borer. The Southwestern corn borer has become a very destructive pest in the South. Resistant types are not yet available and a combination of early planting and use of insecticides offers some measure of control. Corn planted between April 10 and June 1 in Mississippi was severely damaged by the Southwestern corn borer in 1962.

c. Factors in European corn borer damage. Studies were conducted on the influence of fertilization and plant populations on yield reductions caused by leaf-feeding of the European corn borer. The results obtained indicated that (a) yield reduction due to borer feeding was slight for single-crosses involving resistant parents, (b) yield reductions increased with increases in plant populations, and (c) yield reductions increased with fertilization. First brood leaf feeding resulted in greater yield reductions than did second-brood feeding though reduction in yield was significant in both cases.

d. Carbohydrate metabolism. In basic studies on carbohydrate metabolism conducted in India under a PL-480 project, and using tapioca as the test plant, alkaline fructose -6:6- diphosphatase appears to play an important role in the photosynthetic fixation of carbon dioxide.

2. Sorghum.

a. Xenia. The problem of xenia was extensively explored at Lincoln, Nebraska. The F_1 seed from crosses of sterile x restorer lines exhibited a significant increase in both seed weight and seed volume. Hybrid seed also developed at a faster rate than the parental types and reached physiologic maturity in a shorter period of time.

b. Seed dormancy. Periodic harvests were used to determine the effects of moisture at time of harvest and drying temperature on dormancy. Dormancy was more pronounced and persisted for a longer period when seed was dried at temperatures of 100 to 110 F° rather than 70 to 80 F° . Dormancy was also related to the initial moisture content of the seed being more pronounced in samples having higher initial moisture content.

c. Protein content in developing grain. Crude protein was determined on developing seeds for the period 10 to 50 days following pollination. Protein percentages were highest for the first harvest, decreased for succeeding harvest finally reaching a constant level at about the time of physiologic maturity.

d. Planting rates. Plant population studies have been conducted for three years at the Ft. Hays Branch Station in Kansas. The differences between 18 and 36 inch rows was not significant. The highest yields were obtained from the lower plant populations, 10 to 17 thousand plants per acre.

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WHEAT AND RYE CULTURE,
BREEDING, DISEASES AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. Wheat and rye are grown under a wide variety of conditions in the United States. Consequently, a broad array of environments, diseases, market outlets, etc., are met. The problem involves breeding better adapted varieties with resistance to pests that will give good yields to the farmer and have high quality in the market place. Specific aspects of the problem may be very different in different geographical areas; hence, a program of work at many locations is required.

PROGRAM

The Department has a long-range program of research and research leadership in wheat and rye investigations. The objectives of the research are to stabilize production by reducing losses, to increase efficiency of production, to improve the quality of wheat and rye wherever grown in the United States, and to accumulate and disseminate knowledge. This basic and applied research program is performed in the laboratory, greenhouse or field, and involves the sciences of agronomy, ecology, physiology, genetics, cytology, pathology, entomology, chemistry, physics, and statistics. Regional and national leadership is given to several phases of the work.

The primary Federal effort is concentrated in 10 research centers. Twelve additional locations are required either to provide proximity to the location of the problem, or to take advantage of facilities or contacts with workers located at such stations.

Basic and applied work on three rusts of wheat, four smuts, two Septoria diseases, four viruses, several root rotting organisms, mildew, and numerous other diseases to obtain means of control receive the attention of 19 professional employees. In four centers quality testing and evaluation of varieties and basic chemistry and technology research utilize 20 professional employees. The numerous aspects of quality come into prominence in all breeding programs (state, federal, or private), and chemical treatments, soil management and farm handling practices all have an influence on levels of quality that may result in what the farmer sells. Basic work on wheat genetics and the development of improved germ plasm and breeding of new varieties involves 18 professional workers. Included is basic work to transfer useful genes to wheat from other species of plants, learn the inheritance of important characters, study,

catalog, and maintain the World Collection (about 17,000 accessions), and breed new types of wheat for special purposes (e.g., semidwarfs, higher protein flour, more combinations of genes for insect and disease resistance). Leadership in each of the four major wheat regions facilitates state-federal regional planning of certain tests, obtains uniform quality tests, and promotes exchange among workers of seed stocks, data, and useful information. Culture, physiology, hardiness, stand establishment and other such problems utilize 3.4 professional men. The cost of this research is estimated at about 2¢ per harvested acre of the crops concerned.

Under the Public Law 480 program six wheat and rye research projects are sponsored in Poland, Egypt, Spain, and Israel. These include work on rusts, smuts, and root systems of wheat, natural hybridization in relation to the origin of wheat and rye, and the use of polypoidy in rye breeding.

PROGRESS

A. Breeding and Genetics

1. Hybrid Wheat. Research in Nebraska and Kansas revealed a restorer mechanism for use with timopheevi male sterile stocks. This discovery makes possible for the first time an opportunity to study heterosis in wheat on a field scale and to determine the economic feasibility of hybrid wheat. Irrespective of its economic use, the system will permit population genetics experiments with wheat heretofore quite limited by the requirement of hand pollination in ordinary stocks. Seed stocks are being made available to breeders.

2. New Varieties. New varieties released jointly by ARS and one or more States are given below.

Three new winter wheat varieties were released and certified in Nebraska in 1963. They are Gage (C.I. 13532), Scout (C.I. 13546), and Lancer (C.I. 13547). All are highly productive and possess the Hope resistance to stem rust. Other important characteristics of Gage are leaf rust resistance, moderate resistance to soilborne mosaic, moderate hessian fly resistance, resistance to loose smut, and early maturity. Scout has excellent tolerance to streak mosaic, some degree of resistance to hessian fly, resistance to loose smut, early maturity, and excellent quality. Lancer has good winter-hardiness, moderately early maturity, stiff straw, and excellent quality. Gage is best adapted for southeastern Nebraska, Scout for south-central and southwestern Nebraska, and Lancer for all areas of the State except the southeastern and south-central cropping districts. An estimated 1200 bushels of Gage, 1200 bushels of Scout, and 500 bushels of Lancer will be available for distribution in 1963.

Crim is a new hard red spring wheat variety released in Minnesota. The variety (C.I. 13465, Minn. II-53-404) has given excellent yields, has high resistance to stem rust and good quality. About 900 bushels were distributed.

Knox 62 became available to certified seed growers in the fall of 1962 in Indiana and nearby States. It has resistance to hessian fly and generally shows less loose smut than Knox. It has earliness, good yield, and high quality similar to Knox.

Reed also became available in the fall of 1962 through the Indiana program. It is a soft red winter wheat of the Dual type that is superior to the latter variety in yielding capacity, grain quality, and straw strength.

3. Gaines Semidwarf Makes Record Yield. What appears to be a world record yield of 155.5 bushels per acre was established by Gaines on 11 acres in Washington. Increase of the variety was from 75 bushels in 1960 to 700,000 bushels in 1962 in Washington, Oregon, and Idaho. The 1963 acreage of this variety is estimated to be nearly one million acres.

4. Semidwarf Clubs and Other Types. Progress in breeding for semidwarf clubs equaling Gaines in efficiency of production is slow but encouraging. The two best ones performed favorably with Gaines in the regular variety trials but were more severely damaged by stripe rust. However, when compared with Omar these two represent very good progress. Even more encouraging progress appears to be represented in the several thousand new F_3 plant selections made from crosses of Selection 101 and Gaines with several of the semidwarf clubs.

Semidwarf hard red spring and hard red winter types showed good performance in Idaho, Utah, Montana, Texas, and Nebraska trials. Semidwarf durumms presently available are deficient in quality of seed and semolina color but under favorable conditions they give good yields.

5. Genetics of High Protein Content in Wheat. In Nebraska tests, grain protein in the crosses studied was a highly heritable characteristic; two or more genes conditioned high protein in the crosses studied; one of the genes for high protein was closely linked with a gene for leaf rust resistance in Atlas 66; the linked protein gene may be dominant in effect but there is no evidence of a preponderance of dominant genes for either high or low protein. The high grain protein was attainable without sacrificing yield or other agronomic and most quality characteristics.

6. Durum Makes Comeback. The year 1962 was an outstanding one for durum production. One grower in North Dakota reported a yield of 83 bushels per acre from a ten-acre field of Wells. While high yields were due primarily to excellent growing conditions, high yield potentials of the new varieties, Wells and Lakota, added to the making of a bonanza crop.

Langdon, released six years ago, was heavily attacked by a 15B biotype of stem rust. Late-planted fields showed infections reminiscent of those severe rust years of 1953 and 1954. Early-planted Langdon was not damaged seriously, but because it was so susceptible in 1962, it was removed from the list of durum varieties recommended for the durum triangle of North Dakota for 1963.

Wells and Lakota remained resistant to stem rust. However, some rust was found in both of these varieties and they are being repurified.

7. Breeding for Stripe Rust Resistance Expanded in Washington, Oregon, and Other Western States. A greatly stepped-up breeding, genetics, and pathology program on stripe rust was initiated 2 years ago. Research is well established along lines coordinated to relieve duplication among workers.

A number of crosses were made in Oregon with the objective of incorporating the stripe rust resistance of P.I. 178383 with the stem rust resistance of the spring wheat varieties produced by the Idaho breeding program. The stripe rust resistance of P.I. 178383 has apparently been combined with the excellent 5-gram mill performance of HRP-Clarendon. The stripe rust resistance of P.I. 178383 has been observed in many Omar⁴ backcross derivatives. The fifth backcross was made to incorporate the resistance of Suwon 92 into Omar and Burt.

Varieties which have shown good greenhouse resistance to stripe rust are Nord Desprez, Alba, Druchamp, P.I. 94395, P.I. 178383, Staring, Heines VII, Selkirk, Saunders, Thatcher, Atson, Sonora, and Suwon 92. Work in Washington showed that three distinct pathogenic types of stripe rust are present in the region.

8. Translocations from Agropyron Hybrids. In recapitulation of the work done on this project since its beginning in 1959, a total of 9 translocations have been recovered from the first lot of 500 X_0 seed. Results with the second lot of 620 X_0 seed though less advanced indicate up to 12 more translocation types may be at hand. These figures may have to be revised downward after complete and exhaustive cytogenetic analysis has been conducted with each. However, both genetic and cytological data support these estimates. The mere fact that in 5 cases translocation types have been recovered in which the inheritance pattern for leaf rust follows a simple monofactorial type of inheritance indicates a high degree of success in this project.

9. Cause of Sterility in Wheat-Rye Hybrids Sought. When the self-fertile species Secale vavilovii was used instead of self-sterile common rye in the production of an amphiploid with Chinese Spring wheat, the resulting allo-octoploid was highly sterile. Therefore, the less than full fertility of wheat-rye amphiploids probably has other causes than self-sterility of the rye.

A P.L. 480 project in Spain (E-25-CR-5) involves development of several autoploid ryes from inbred and ordinary varieties and new amphiploids of wheat crossed with rye to improve fertility and increase disease resistance in rye.

10. "Pairing Gene" Basic to New Theory of Evolution of Wheat. Of great significance in wheat cytogenetics was the recent discovery (in Missouri and England) of a gene that prevents the pairing of related (homoeologous) chromosomes without appreciably interfering with the pairing of homologues. It now seems clear that when tetraploid wheat arose, through chromosome doubling in a hybrid between two closely related species, its chromosomes paired irregularly, with numerous multivalent associations. Fertility was consequently low, and survival of the new species was in doubt. A mutation to prevent homoeologous pairing would allow only bivalent pairing and thereby result in full fertility.

In wide hybrids, with the pairing gene absent, up to ten times the normal amount of pairing may occur. In order that the fullest use may be made of the chromosome-V effect, as it is called, the increased pairing must be obtainable in another way than through complete deficiency for chromosome 5B (V). Therefore, in collaborative work, X-rays have been used to knock out the locus of the pairing suppressor. Three deficiencies have been obtained and are to be tested for male transmission and homozygote vigor.

11. Chemical Mutagens Give New Genetic Markers. A number of mutants were obtained in Missouri using ethyl-methane-sulfonate that were different from those resulting from ionizing radiation. Included was a chlorophyll mutant, apparently a simple recessive. It seems clear that EMS induces frequent gene changes in wheat, while the effect of X-rays is almost exclusively the production of duplications and deficiencies. It may be possible with EMS to obtain enough mutants suitable for genetic studies to permit the mapping of all the chromosomes of wheat.

Two "banded-shrivell" mutants and a virescent seedling mutant were induced by ethyl sulfate in Wells durum in North Dakota. Each appeared to be controlled by a single recessive gene.

12. Inheritance of Bunt Resistance. F_4 data support interpretation of F_3 data in regard to the number of genes which condition bunt resistance of P.I. 178383, P.I. 178210, and P.I. 116306 to bunt (Oregon). Resistance is conditioned by three, one and one genes, respectively. Resistance is dominant in all 3 varieties. Monosomic studies indicate the T and R genes are located on chromosome 1. Bronze chaff factor in Golden is also on chromosome 1 which supports reports of linkage between T, R, and the bronze chaff factor.

13. Crown Roots and Lodging Related. In a P.L. 480 project in Israel (A10-CR-3), the development pattern of crown roots in early maturing wheats proved to be quite different from that seen in certain late maturing varieties. Varieties differing in lodging rates have been incorporated into crosses to study the relation of roots and lodging.

B. Diseases

1. Stem Rust Continues to be Serious Threat. The Uniform and International Rust Nursery programs were continued. Results from 1961 and 1962 indicate that in some locations (Kenya particularly) almost none of our sources of stem rust resistance are effective. This indicates that a more intensive search for resistance must be initiated and other means of control investigated. Tests in Puerto Rico were at 3 locations. The 1962 IRN comprised 600 entries of spring wheat at 64 locations and 300 winter wheats at 32 locations.

New races of stem rust have been discovered on the North American continent which in seedling tests conducted by the Cooperative Rust Laboratory in the greenhouse are virulent on many common wheats resistant to the previously known races. Races 11E and 11F, especially, and 15B-4 are important in this respect since they are virulent on most of the following wheats: Selkirk, Frontana x K58/Newtatch, Kenya Farmer, Bowie, Pembina, Canthatch, and Sr6, Sr7, Sr8, Sr9, Sr10, and Sr11 substitution lines. However, Justin, Milam, the wheat-rye translocation and substitution lines of Acosta and Sears, and a number of durums are resistant to these races. Certain of these cultures are to be used in Puerto Rico tests in 1963-64.

Stem rust caused losses of 1/4 to 2/3 of the winter wheat crop in certain central and north-central States. These losses are attributed to susceptibility of the winter wheat varieties grown to physiologic race 56. In contrast, losses in spring bread wheats were negligible because the widely grown varieties Selkirk and Conley are resistant to race 56 and cultures of race 15B that prevailed. A small loss in durum wheats is attributed to the susceptibility of Langdon to a culture of 15B (15B-2). Lakota and Wells, released in 1960, were resistant. It is estimated that about 50% of the durum acreage consisted of these varieties.

A broader attack on this disease is made possible by a P.L. 480 project (E-25-CR-3) in Spain where types representing a wide range of pathogenicity have been collected, some differing from those in the USA. Another is being initiated in India.

2. Ecology of Rust. Further experiments confirmed and extended previous findings of differences in incubation period in rust races. Apparent differences in sporulation were observed at various temperatures. The ability of stem rust race 56 to develop more rapidly than 15B under Kansas conditions (and at lower temperatures) was demonstrated by pustule counts on artificially inoculated plants. A less efficient infection phenomenon seen in 'Klein Cometa' appears to be inherited based on F₃ progeny inoculated at Minnesota.

Rust movement across Texas was studied. A heavy spore shower caused a build-up of stem rust in the Iowa Park and Sherman areas which in turn supplied inoculum for the rust epidemic that occurred in Kansas and Nebraska.

3. Liquid Nitrogen Storage of Rust. The utility of liquid-nitrogen storage of rust inoculum has been demonstrated. Use of this method in other labs should increase quality and quantity of work with the same facilities previously available plus a liquid-nitrogen refrigerator.

4. New Leaf Rust Differentials Explored. The genes for resistance to leaf rust races 9 and 15 have been bred into a Wichita background by crossing Wichita with each of the differential varieties followed by repeated backcrossing to Wichita. They were in the 4th to the 6th backcross in 1962 and all appear to be typical Wichita from the standpoint of plant characters. These lines were compared with the standard differentials by simultaneous tests with 10 of the most widely known races in the US, and to many other cultures. For many races the backcross lines gave the same reactions as the standard differentials but always placed the races in the same unified group. These backcrosses would have many advantages because the seedlings are all alike morphologically.

A P.L. 480 project (E21-CR-4) in Poland has shown the presence of races of leaf rust useful in identifying new sources of resistance. Two such varieties have been made available.

5. Chemical Control of Rust. In Minnesota, using an isolated plot technic, studies of the relations between inoculum production, epidemic development, and chemical control of leaf and stem rusts on Marquis wheat indicated that rate of inoculum production might be used to forecast epidemic development by 5 to 7 days, that suppression of inoculum production by chemicals has a role in the control of rust epidemics, and that treatments of Dithane S-31 are most effective against epidemics of rust when applied at a rust incidence of 10 to 100 uredia per culm.

Dithane S-31 applied to spring wheat in Minnesota by an airplane and to winter wheat in Kansas controlled a leaf rust and a stem rust epidemic, respectively, and appeared to be financially profitable. In the Kansas test, two applications of 3 pounds each reduced rust readings from 35% to Trace. Loss of effectiveness of nickel in wheat seedlings against infection by stem rust is associated with declining concentrations in the treated tissue as the nickel is redistributed through the untreated portions of the plant.

6. Host-Pathogen Metabolism Studied. Niacin and pantothenic acid contents of infected plants begin to increase with the development of internal stem rust mycelium and rise significantly as the fungus sporulates. Vitamin B₆ does not rise with the progress of the disease. Inherent differences in concentration of the 3 vitamins between resistant and susceptible varieties of wheat did not account for their resistance or susceptibility. The rise of niacin and pantothenic acid level in the diseased-host tissue is an effect of infection. Stem rust uredospores are very rich in fat, in niacin, and pantothenic acid, but not in vitamin B₆.

Symptoms of powdery mildew in heavily infected leaves were divided into two stages: young infections and at time of sporulation. The first stage was one of delayed senescence in which host tissues had respiratory rates twice those of healthy tissues, increased dry weight and retardation of nitrogen loss. Since similar symptoms are produced by chemical senescence inhibitors, it is likely that symptoms of young mildew infections are produced by an inhibitor of senescence. When the mildew sporulates, this stage is characterized by an increase in respiration to rates three times those of healthy tissue, by maintenance of dry weight, and by a marked loss of nitrogen. There is an equivalent gain in nitrogen by spores of the mildew. The chlorosis which accompanies this second stage, as well as the nitrogen loss, suggest that the tissues are in a state of accelerated senescence.

7. Stripe Rust (See also A - 7). The finding that Golden, Red Russian, Norin 10, and Norin 10-Brevor 14 were highly susceptible to stripe rust in all stages of plant development under field conditions was of significance to plant breeders. These varieties had shown good stripe rust resistance prior to 1962. The cause of the reversal in varietal behavior is unknown, but it is known that three diverse pathogenic cultures of stripe rust exist in the Northwest and that climate alters the expression of resistance.

The effect of stripe rust on yield and test weight was measured at Washington in near isogenic lines of Burt of varying height levels. These lines also varied as to presence or absence of so-called "adult stripe rust resistance." Susceptible isogenic lines yielded from 7 to 30 bushels per acre; adult resistant lines ranged in yield from 39 to 63 bushels per acre. Susceptible lines of short height level produced 82% less than their adult resistant sibs, while within the intermediate height group susceptible lines yielded 55 to 73% less than their resistant sibs; in the tall height group the difference between susceptible and adult resistant lines was 40%. Test weights ranged from 40.0 to 53.5 pounds per bushel for susceptible and 48.9 to 58.4 pounds per bushel for adult resistant lines. Variety trials in Montana showed large reductions in yield but not in test weight.

The high degree of resistance of the variety Nord Desprez was found to break down when this selection was infected with L-7 race of common bunt under field conditions. This reaction was noted when the smut infected plants reached the flag leaf stage.

8. Mildew. Significant changes in the mildew population were indicated by infections on varieties that had been resistant. Increased virulence of the pathogen was noted in Michigan, New York, Pennsylvania, and Maryland. Knox and Redcoat, two important soft winter wheat varieties that have been resistant, sustained considerable damage in 1962. The search for new sources of resistance was continued.

Through a series of backcrosses the diverse genes identified in the commonly used differentials, and some other varieties, including varieties from species other than the hexaploids, have been transferred to a common background in Chancellor. About 35 sources, some of which carry identical genes, are involved. About 40 wheat varieties have been screened to 34 cultures of mildew although over 250 varieties have been screened to several cultures and about 1000 wheats have been screened to one or more cultures of mildew.

9. Smut Research. In view of the apparent increasing scope of cereal disease problems in the Pacific Northwest and considering the current low incidence of bunt, the activities of the Regional Smut Research Laboratory are gradually expanding to include disease problems other than smuts. Therefore, the name Regional Smut Research Laboratory has been changed to Regional Cereal Disease Research Laboratory.

Collection 742, originally collected from the variety Cache near Malad City, Idaho, has been designated as a new race, T-19. It is similar to race T-13 in pathogenicity but in addition attacks resistance conditioned by the M₂ factor of Martin resistance.

Data obtained indicate that sexual compatibility between 2 lines as determined by the fusion of secondary sporidia, does not necessarily insure infection by such a combination. Something other than a simple plus and minus relationship is involved in the matings between certain isolates.

C.I. 7111 appears to carry resistance to all key races except L-7. P.I. 173501 appears to carry some unknown factor or minor factors for resistance to race T-15 alone. Two Elgin-type wheats, one carrying the Hohenheimer-type resistance and the other carrying the Hussar factor for resistance, have proved to be adequate replacements for the differential varieties Hohenheimer and Selection 1403, respectively. Omar 144 will be substituted for Omar 140 among the differential varieties since it is more susceptible to race T-18.

A Brevor-Idaed cross has some unknown factor since it is resistant to race T-15 while being highly susceptible to races T-13 and T-16. There is no previously known factor or combination of factors which conditions this type of resistance.

Of 57 wheat entries screened for resistance to dwarf bunt race D-3, only P.I. 178383 remained completely smut-free. Other entries exhibiting high resistance were P.I. 173438, P.I. 167556, P.I. 191096, P.I. 166910; 49-8.2, and Requa. Delmar exhibited high resistance to race D-3 in tests at Pullman, Washington, but was found to be moderately susceptible in tests at Kalispell, Montana.

Time of infection studies with dwarf bunt have shown over a 5-year period that infection occurs from mid-December to April and that the greatest amount of infection takes place during January.

Infection by seedborne spores of flag smut was best at 15°C and in soil that was relatively dry, in this case 13 percent moisture on an oven dry basis.

Nutrition studies with flag smut infected plants revealed that nutrition did not affect sporulation in the leaves and that similar percentages of flag smut developed in all nutrient solutions and in distilled water.

Control of seedborne plus soilborne common bunt was obtained only with formulations of HCB and TCNA. TCNA at 2 ounces per bushel was particularly effective this year.

Good control of dwarf bunt was obtained by soil-surface applications of HCB, TCNA, and PCNB in experimental plots in Washington. Good control of dwarf bunt was also obtained by soil-surface applications of HCB and PCNB at 2-1/2 to 10 pounds per acre under field conditions near Kalispell, Montana where high percentages of infection occurred in untreated plots. Aerial applications of HCB in western Montana reduced the incidence of dwarf bunt from 68.7 percent in the untreated areas of a field to 4.6 percent in the treated portion (4.74 acres).

10. Bunt Fungus Sporulates in Culture. The dwarf bunt fungus was readily isolated from infected young wheat kernels. The isolated hyphae grew well and produced teliospores in sterile culture. However, subcultures of the isolated hyphae gradually lost their capacity to produce teliospores and were demonstrated to be non-pathogenic. Observations indicate that physiologic and pathogenic changes occur in the fungus soon after its isolation from host tissue.

11. Virus Resistance in Agroticum Theorized. From observations in Oklahoma certain deductions regarding streak virus resistance can be made. First, the frequency of susceptible types is related to the high frequency with which alien monosomes (present in the F_1 's) are lost during meiosis. Second, the varying shades or degrees of tolerance (or resistance) exhibited by the F_2 population seem to be related to a dosage effect of the genes carried on differing numbers of chromosomes--43, 44, 45. Third, the low frequency of recovery of the immune parental type seems related to the low frequency with which the original complement of chromosomes is reconstituted from the monosomic condition in the F_1 . Lastly, though not conclusive, the results seem to bear out the hypothesis that genetic material from both pairs of chromosomes is essential for the expression of the immune type of reaction characteristic of the parental material.

12. Snow Mold Testing Technic Developed. Growth chamber and greenhouse procedures were developed in Idaho for screening varieties for resistance to snow mold or, more properly, recovery from attack. This consists of a system to hold test plants under a snow pack for 5 weeks followed by a recovery period.

13. Rye Diseases. Gator and Florida Black rye grain yields have declined during the last 4 years in northern and northwest Florida. The occurrence of heavy infections of Colletotrichum graminicolum (anthracnose) have been associated with low yields. Wrens Abruzzi showed some tolerance. Roots, rarely infected, were severely damaged in 1962. Resistance and control measures are being sought.

As a further aid to breeding disease resistant rye, a P.I. 480 project in Spain has yielded doubled stocks of wheat-rye amphiploids. Several autotetraploid forms are being developed.

C. Variety Evaluation (Quality Studies)

1. New Varieties Released have Good Quality. (See A - 2).

2. Impact of Gaines on Quality. Gaines, a new soft white wheat, may change the character of the Western White market subclass. Gaines is very similar to Brevor in milling and flour properties. By 1964, Gaines may make up 60 to 90% of the Pacific Northwest wheat crop. Thus, the average composition of the market subclass Western White will change from predominately excellent milling, low viscosity club wheat to harder to mill, moderate viscosity soft white wheat.

Fear that the average protein content of the white wheat would increase as the result of the wide-spread production of Gaines is unfounded. The evidence available indicates that even with the much heavier applications of nitrogen fertilizers recommended for this variety, there may be a slight decrease in the average protein content of the crop under the same weather conditions that produced previous crops because of the much higher yield Gaines makes. "Luxury" amounts of N produce higher protein wheats.

3. Differential Varietal Response in Dry vs. Irrigated Treatments. Wheat varieties classified as stable under both treatments sometimes become unstable when irrigated. Mellow gluten hard winter varieties weakened more often under irrigation than strong gluten forms.

4. Triumph Wheats Similar. No one of 4 Triumph wheats was consistently best or poorest when grown at 4 locations in Oklahoma. The Triumph wheats had similar overall quality characteristics. If a preference had to be indicated, it would be in favor of C.I. 12132.

5. 2,4-D Safe. Bison wheat was sprayed with various quantities of the dimethylamine salt, isopropyl ester, and isooctyl ester of 2,4-dichlorophenoxyacetic acid at 3, 2, and 1 week before ripe at Hays, Kansas(CPRB). Deviations in absorption, mixing time mixogram, corrected loaf volume, and other bread baking properties within and between treatments were no greater or less than would be expected for replications of any given treatment. Thus, none of the chemical, milling, or baking properties of Bison wheat were affected by the spraying treatments.

6. Free Amino Acid Content of Varieties During Development. Kaw and Pawnee wheat harvested at various stages of maturity from 27 days preripe to ripe were used to follow the changes in free amino acid contents during maturation and gluten synthesis. Flours from these samples were subjected to two-dimensional paper chromatography. The concentration of each amino acid as well as the number of amino acids (24 for Pawnee and 25 for Kaw) decreased materially and progressively, in general, as the wheat kernel developed and matured, to such an extent that only 7 of the 24 or 25 detected at an early stage were in sufficient concentration at the ripe stage to be detected. Baking data showed that gluten protein synthesis was taking place during the period when the concentrations of free amino acids were highest.

The two amide amino acids glutamine and asparagine are among the most abundant amino acids at all stages of maturity. This may be of significance when considering the origin of the purported high amide N value of wheat gluten. Several non-protein amino acids were found in both Pawnee and Kaw at the earliest stages of maturity.

7. Quality Changes with Maturity. Kaw wheat, which usually has a somewhat low loaf volume potential often labeled as questionable, has, at 17 days before ripe, a volume potential that is more than 100 cc. above normal and superior to that for Pawnee at a comparable stage of maturity. Loaf volume potential of Pawnee is excellent. Proteolytic activity of Pawnee and Kaw wheats and flours was highest for the earliest stage of maturity and fell off sharply to a minimum at 19 days before ripe, remaining approximately constant thereafter to ripe.

8. Sedimentation Values Reflect More Than Protein Differences. Material obtained by milling on Tag-Heppenstal moisture meter rolls was not representative of the total wheat endosperm, thereby accounting for some variation in sedimentation results. Low correlation of sedimentation with loaf volume and difficulty in blending for a specific sedimentation value are partially explained by this. Variation in wheat hardness appears to account for at least part of the inconsistent and peculiar variation in protein content of wheat and Tag flour. Protein quantity and quality differences that are reflected in loaf volume above 1000 cc. essentially are not manifested by sedimentation, primarily because protein contents above 14 to 15% in good quality samples are not clearly identified by the sedimentation test. A modified procedure has helped alleviate this limitation.

The flour from four varieties was fractionated and part of the crude starch from each variety was ball milled before reconstitution. None of these reconstituted flours gave normal-looking sedimentation tests, and those with ball milled starch were most abnormal. Apparently, the treatment so altered the various flour components that no useful data could be obtained from the sedimentation test. After an hour's ball milling, flour from these same four varieties all showed increased sedimentation volumes and the soft pastry flour was placed in the bread flour range. The increase in damaged starch and/or alteration of other flour components may account for the change.

In Ohio, sedimentation values on flours from Seneca wheat dried at 130°C to 260°C showed a rise to a temperature of 210°C, followed by increasing loss of volume at temperatures above this value. Pearling index rose with drying temperature, indicative of a kernel softening effect of heat.

9. Soy Flour Bread. Bread-baking potentialities are affected by a number of variables in the manufacture and composition of soy flour (used at approximately a 2.5% soya protein level). Soy grits had a less deleterious effect than finely powdered soy flour in Kansas tests. Heat treatment tended to lower bread-baking potentialities, but the effect of such treatment was less pronounced in coarse soy-meals than in soy flour. The addition of fat or lecithin had a beneficial effect. Water non-dispersible soybean protein isolate reduced oxidation requirement, but otherwise was comparable in its action in bread baking to properly treated soy flour. Water-dispersible protein isolates and 70% protein concentrates had a deleterious effect. The use of toasted soy grits gave more appetizing breads and overcame the somewhat objectionable brown color of breads containing finely powdered soy flours.

10. Effect of Amino Acids and Sugars on Bread. Three amino acids and 17 sugars were added and their effects on bread evaluated. No deleterious effect of .2 to .8% free amino acids or up to 4% sugar was noted on bromate requirement, mixing time, or water absorption. Color of crust was altered in some instances and loaf volume sometimes was reduced.

11. Pearling Predicts Break Flour. A statistical study in Ohio of the relationship between pearling index and break flour yield showed that for 759 samples of the variety-protein and eastern uniform nursery series, covering as many as 12 crop years, a correlation coefficient of 0.8335 was obtained. This value, cleared of confounding effects of season and location, indicated the great probability that break flour yield is associated with kernel hardness.

12. Micro Test Procedures for Soft Wheat Quality. Development of a 10-g. milling procedure, a small scale pearling test, and a micro AWRC test, and the clarification of the relationship of test results to quality factors resulted in a routine procedure for the processing of large numbers of small quantities of grain for milling and baking quality evaluation. It is estimated that about 34 minutes actual processing time is required per sample for complete results. This facilitates studies of genetic populations.

D. Culture and Physiology

1. Emergence Rate. Rapidly emerging types of wheat include Nigger, Spinkcota, Dickson 114, and P.I. 178383. Among 527 hybrid selections observed in Washington, 463 rated inferior to Gaines in speed of emergence, but 64 lines exceeded the emergence ratings of (14 x 53)B5, presently the most rapidly emerging semidwarf. None of the lines emerged as rapidly as Dickson 114 or Spinkcota. Two of the most rapidly emerging lines were from a compound cross between (Nigger x Sel. 101) x Gaines.

The cross SD Sel. 25 x P.I. 178383 gave very rapid emerging semidwarf selections. Several of the P.I. 178383 derived semidwarf lines placed above Omar in emergence rate. In general, they have weak straw, light grain of rough texture, brittle rachis, and thresh poorly.

2. Hydroponic Culture Masks High Protein Genotypes. Atlas 66, Wichita, and Comanche were studied under 3 nutrient regimes in Nebraska in which the availability of nitrogen was the principal variable. It was possible to markedly alter the protein content of the grain produced by the 3 varieties by controlling nitrogen in the nutrient solution. The established grain protein superiority of Atlas 66 over Comanche and Wichita was not expressed under any of the nutrient regimes. Reasons for this are unknown at this time.

3. Vernalin Sought in Wheat. It was found that Elgin could be vernalized in the dark, in aerated distilled water without the addition of exogenous organic or inorganic substances. It was further shown that during vernalization in aerated distilled water biologically-active substances associated with the vernalization response diffuse into the aqueous medium. Despite the loss of such diffusible substances the wheat seedlings still retained the flowering response induced by the cold treatment. Diffusates obtained from the spring wheat, Red Bobs, stimulated the treated plants to grow taller and head earlier than control plants. Diffusates from the winter wheat, Elgin, had the opposite effects; that is, shorter plants and later heading. Light quality during the vernalization process had no consistent effect on heading in winter wheat, but winter barley seedlings exposed to either red or far-red light during the cold treatment headed much earlier than similar plants exposed to either white or black light. The external application of nucleotides (10 compounds), oxidation-reduction reagents (11 compounds) and a lipid anthogen hormone extract to nonvernalized winter wheat seedlings appeared to have little or no effect on the growth of the terminal meristems or the flowering response of the wheat plants.

4. Soil Moisture Before Sowing, A Factor in Wheat Quality. Protein quality was higher in Cheyenne wheat from plots where the preplanting moisture was high in an experiment at North Platte, Nebraska. Moisture levels were 0, 2, 4, and 6 feet of soil wet to field capacity at sowing time plus normal rainfall.
5. 8-Row Seeder Perfected. An 8-row seeder with 8 wheels to provide even packing to the land was put into operation at Pullman, Washington. A 3-man crew can sow one 8-foot row per second on a nonstop schedule.

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OAT AND BUCKWHEAT CULTURE
BREEDING, DISEASE, AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. Most of the United States oat crop is produced under warm, humid conditions highly favorable for disease development. The major limiting factors for profitable oat production in the United States have been the heavy damage resulting from oat diseases and winter killing. Oats, more than any other cereal crop, have suffered from a succession of severe epiphytotics of new or different diseases and have experienced several rapid and nearly complete consequent change-overs to resistant varieties. Because of the constant acute need for new disease-resistant varieties, it has not been possible to give adequate attention to improving straw strength, adaptation, nutritive value, winter hardiness, yield, grain and forage quality, etc. A widely deployed but intensive research program is essential to cope with the diverse problems affecting the oat crop.

Buckwheat has been long neglected from the standpoint of breeding for increased yield, grain quality, straw strength, disease resistance, adaptation, etc. There has been no record of any surplus of buckwheat. Information is needed about physiology and cultural methods, including effect of temperature, date and rate of sowing, fertilization, rotation, bee pollination, hormone application, etc., in order to increase the stability and efficiency of production.

PROGRAM

The Department has a continuing long-term research program involving pathologists, geneticists, and agronomists engaged in both basic and applied research in an attempt to solve the problems besetting the oat crop. The ultimate objective is to stabilize production, increase efficiency, and improve the quality of oat grain and forage wherever it is grown. Most of the work on the breeding, genetics, and disease of oats is conducted in cooperation with the State Experiment Stations at Gainesville, Florida; Tifton, Georgia; Aberdeen, Idaho; Urbana, Illinois; Lafayette, Indiana; Ames, Iowa; Manhattan, Kansas; Beltsville, Maryland; St. Paul, Minnesota; Stoneville, Mississippi; Columbia, Missouri; Ithaca, New York; University Park, Pennsylvania; Brookings, South Dakota; College Station, Texas; Blacksburg, Virginia; Pullman, Washington; and Madison, Wisconsin. The World Oat Collection is maintained and distributed from Beltsville, Maryland, with increases of the collection being grown in cooperation with State Experiment Stations at Mesa, Arizona; and Aberdeen, Idaho.

Oat research is being conducted under three P.L. 480 contracts. One in Poland, E21-CR-4, covers a wide range research on cereal rusts, including crown rust of oats. The second in Colombia, South America, S5-CR-2, covers research on extremely virulent races of oat stem rust. The third in Israel, A10-CR-20, covers research on collecting and screening five native wild species of oats for resistance to virulent races of stem and crown rust.

Buckwheat breeding and genetics are limited to an industry supported graduate student at University Park, Pennsylvania.

The Federal scientific effort devoted to research in this area totals 12.8 professional man-years. Of this number 5.2 is devoted to breeding and genetics; 7.0 to diseases; and 0.6 to program leadership.

PROGRESS

A. Breeding and Genetics

1. Improved Oat Varieties. Clintland 64 (C.I. 7639) is an improved backcross derivative of Clintland and Clinton developed in cooperation with the Purdue University Experiment Station. Clintland was crossed with [Landhafer x (Mindó x Hajira-Joanette)] x Andrew, Minn. 313, and the F₁ progenies backcrossed four times to Clintland--selecting in each generation for the ABCD stem-rust resistance inherited from Minn. 313. Clinton 59 was crossed with Grey Algerian and the F₁ progenies backcrossed five times to Clinton 59--selecting in each generation for the Grey Algerian type of crown-rust resistance. A stem-rust resistant (ABCD genes) and crown-rust resistant (Bond plus Landhafer types) derivative of the Clintland⁵ x Minn. 313 was then crossed with a stem-rust resistant (D gene) and crown-rust resistant (Bond plus Grey Algerian types) derivative of Clinton⁶ x Grey Algerian. Clintland 64, a derivative of the last cross, possesses the combined stem and crown rust resistance of Clintland, Minn. 313, and Grey Algerian. It is indistinguishable from Clinton and Clintland except for its added resistance to stem and crown rust. It is expected that seed of the new Clintland 64 will be available for distribution to growers of certified seed in Indiana and other States in 1964.

Neal (C.I. 7440) is a new early, short, and stiff-strawed oat variety developed in cooperation with the Nebraska Experiment Station from the cross Nemaha x Andrew-Landhafer. The grain is of satisfactory milling quality and variable in color with ivory and light buff predominating. It is heterogeneous for reaction to races 7A and 8 of stem rust and susceptible to races 6, 6A, and 13A. Neal is moderately resistant to some races of crown rust. It appears to have some

tolerance to barley yellow dwarf. Neal has been outstanding for performance in the southeast, south-central and southwest regions of Nebraska.

2. Crown Rust Resistance from Wild Oats. *Avena strigosa*, C.I. 3815, a diploid oat and one of the best sources of resistance to the crown rust fungus, has been crossed to cultivated oats and its gene for resistance carried to the 7th backcross generation in cooperation with the Iowa Experiment Station. Although the chromosome number of seedlings in the 7th generation ranged from 40 to 43 (cultivated oats have 42) the fertility is still very poor. Successful transfer to cultivated oats of this gene for resistance will provide farmers with one of the best available sources of crown rust resistance.

The crown rust resistance of the derived tetraploid Abd. 101 (C.I. 7232) recently transferred to hexaploid oat varieties has been found tightly linked with brown kernel color. This unexpected linkage has interfered with oat breeders utilizing this gene in breeding programs. Evidence has been obtained in cooperation with the Iowa Experiment Station that this linkage can be broken, although the desired combinations have so far been obtained only in highly sterile lines.

3. Improved Crossing Technique. Low seed set following hand pollination has long been a serious handicap in hybridizing oats. High temperature and low humidity have been recognized as important factors in reducing the seed set of hand-pollinated oat crosses. A "wet bag" technique has been developed in cooperation with the Pennsylvania Experiment Station which greatly enhances the success of oat hybridization. The "wet bag" technique consists of emersing glassine or parchment bags in water so they are wet inside and out before they are used to cover the panicles immediately following pollination. The cooling effect and increased humidity resulting from the wet bag technique have resulted in a striking increase in seed set with 60-75% seed set being common.

4. Inheritance of Stem Rust Resistance. A new dominant gene G has been found to control resistance to races 6, 7, 7A, 8, and 13A of oat stem rust possessed by the hexaploid variety, C.I. 2413, introduced from China. In further cooperative studies with the Iowa Experiment Station, C.I. 3030, a hull-less hexaploid variety from Africa, was found to possess two new genes which condition resistance to the same five races. The recently described f gene, the G gene, and the two genes in C.I. 3030 are inherited independently from the B gene, but are either linked or are allelomorphic with the linked A and D genes.

5. Oat Monosomes. Six different oat monosomes from hexaploid oats have been isolated and identified to date in cooperation with the

Iowa Experiment Station. These monosomes have been designated a to f, inclusive. It has been determined that the genes A, B, and D controlling reaction to oat stem rust are not located on monosomes a to f. Several other genes, including the L gene (from Landhafer) controlling reaction to crown rust, have been found associated with specific monosomes.

6. World Oat Collection. During 1962 the World Oat Collection was increased by 82 introductions from 8 foreign countries and by 147 accessions from 16 States. A total of 7,291 envelopes of seed were distributed to 10 foreign countries and 8,038 envelopes to 18 States. The World Oat Collection as now being maintained is composed of 6,929 entries. Oats make up approximately 20 percent of the total USDA World Small Grain Collection.

7. Buckwheat. There are now 153 entries in the buckwheat collections being maintained in cooperation with the Pennsylvania University Experiment Station. Currently of most interest are 7 that were obtained from Russia during 1962. Two of these are listed as tetraploids. A total of 20 collections were grown in isolation during the year, but little seed increase was obtained because of severe drought. The Canadian variety Tokyo was further increased and about 8 bushels of seed are on hand. This variety may be released to growers in the near future. A preliminary increase of a promising Russian tetraploid was also made and about 6 pounds of seed was obtained.

B. Diseases

1. Tolerance to Crown Rust. The project of screening the World Oat Collection for sources of crown rust tolerance was continued at Ames, Iowa. Certain lines were shown to have a higher degree of tolerance than others. A study of the relative tolerance of 25 oat varieties to crown rust races 203 and 216 indicated that varieties tolerant of one of these races would probably also be tolerant of the other race. Bulk populations from crosses involving sources of tolerance were subjected to crown rust in the field. Selection of heavier and denser seed from this material resulted in heavier and denser seed being produced under conditions of heavy rust in the following year. In a preliminary study of the heritability of the crown rust tolerance of Andrew, the yields of F_4 lines formed an array intermediate between Andrew and the susceptible parent, whereas seed weights were skewed in the direction of heavier seeds.

2. Effect of Crown Rust on Components of Yield. Average seed weight, as determined by 100-seed samples, was found in cooperative studies at the Iowa Experiment Station to be a more precise measure of host response to crown rust than either average yield or bushel weight. Seed weight, number of kernels per plant, and number of

plants per unit area are the three basic components of yield in oats. Crown rust infection in Iowa affects primarily only the first of these three components, i.e., seed weight. When yield was used as a measure of the effect of rust infection, it was confounded with factors affecting all of the components of yield, whereas the use of seed weight eliminated all of the factors except those affecting seed weight.

3. Wild Oats Resistant to Crown Rust. A total of 48 collections of the wild hexaploid Avena sterilis, 42 collections of the tetraploid A. barbata, 2 collections of the tetraploid A. wiestii, and 1 collection of the diploid A. longiglumis have been received from Israel through the P.L. 480 contract research program No. A10-CR-20. Two of the collections of A. barbata (D 197 and D 203) have been found in cooperative studies with the Iowa Experiment Station to possess resistance to all (1962) United States collections of rust. The apparent outstanding resistance of these two strains and one collection of A. barbata (Silva 17) from Brazil to race 264 and other extremely pathogenic races of crown rust promises to be of great value. Fortunately, the three strains appear to possess different, single, nonallelic genes controlling their outstanding crown rust resistance. Thus, it should be possible to combine the three genes in one line that would be more resistant than either parent.

4. Crown Rust Race Survey. A total of 633 isolates of crown rust distributed among 24 races were identified from crown rust collections from oats made in 25 States in 1961. Four new races, numbered 326, 327, 328, and 329 were discovered and described. The relative prevalence of races isolated from material collected on buckthorn differed significantly from the prevalence of races isolated from oats. Twelve oat varieties were used as supplementary differentials for crown rust collections made in 1961. The diploid A. strigosa (C.I. 3815) and tetraploid A. abyssinica (C.I. 7233) were resistant to all collections, and others were resistant to important races. Eleven varieties are being used as supplementary differentials for crown rust collections made in 1962. Field surveys showed that crown rust was common on Rhamnus cathartica and rare on R. lanceolata in 1962.

5. Oat Rust Nurseries in Puerto Rico. A total of 7,080 entries of oats were distributed among four isolated oat rust nurseries grown in Puerto Rico during the winter of 1962-63. Separate nurseries were inoculated with the following oat rust races: (1) crown rust race 264, (2) crown rust race group 290, (3) stem rust races 6A and 13A, and (4) virulent biotypes of race 6A of stem rust. Data from the 1961-62 crown rust nurseries in Puerto Rico showed that certain new introductions of wild oat species had good field resistance to the Saia-attacking race 321. The same lines were generally

susceptible to race 264. Studies of the inheritance of the field resistance of several strains of oats in Puerto Rico failed to give a specific factorial hypothesis, but did show that resistance was generally recessive to susceptibility. Studies on hyphal fusion and race competition have been initiated in Puerto Rico.

6. Stem Rust Resistant Germ Plasm. The establishment of an oat stem rust resistance reservoir in cooperation with the Minnesota Experiment Station was initiated at St. Paul, Minnesota, in 1962. The purpose of this reservoir bank is to discover, test, and make available as many different types of resistance as possible to the oat stem rust fungus. The term "type of resistance" as used here implies resistance attributed to physiological, morphological, or functional reasons, as well as "field resistance," "partial resistance," and "tolerance." Such a collection of oats would be valuable as supplemental, differential hosts in physiologic race identification, as possible sources of resistance to newly discovered races and subraces, and valuable in genetic studies with host, pathogen, and host-pathogen interactions. At least one oat possessing each of the major genes, A, BC, D, E, f, and G and all possible combinations of these major genes will be included. At the present time, 102 diploid, tetraploid, and hexaploid oat selections have been increased for entry into the reservoir.

7. Effect of Temperature on Reaction to Stem Rust. The expression of resistance to certain races of stem rust at low temperatures and susceptibility at high temperatures of oats with the BC gene was observed at St. Paul, Minnesota, to depend upon the relationship of two factors: (1) The stage of rust development at the time of exposure to high or low temperature, and (2) the duration of exposure. There is a critical period in the development of the rust pustule, a time between the inoculation and the appearance of rust flecks, when a change in temperature may alter the rust response of the host. Plants transferred from low to high temperature before flecking stage had a susceptible response; plants transferred during flecking were mesothetic; and plants transferred after flecking had a resistant response to races 7 and 8. The minimum exposure to high temperature for the susceptibility of Rodney (BC) to race 8 was determined to be at least 3 and possibly 4 days at a continuously high temperature (85°F); the minimum period of exposure to low temperature for resistant response, when plants were grown at high temperature after inoculation, was found to be 4 days at a continuously low temperature (75°F). The 3-day exposure to 85°F for susceptibility and the 4-day exposure to 75°F for resistance must be initiated prior to flecking by the rust.

8. Smut. The development of a standard group of homozygous pathogenic races ranging from the narrowest to the widest ranges in

pathogenicity patterns is the basic objective of the race study being conducted cooperatively with the Washington Experiment Station. Homozygosity for pathogenicity apparently has been established in several of the races of U. avenae, whereas displays of erratic pathogenic patterns from one year to the next are characteristic of certain other races and genetic lines. A second successful step seems to have been made in bringing all known virulence genes together in one genetic smut line. The Camas virulence of A-7 appears to have been added to A-6a, bringing the total range of virulence in this line to 7 of the tester varieties.

9. Yellow Dwarf Resistance Being Transferred. The barley yellow dwarf virus (BYDV) disease caused the highest average annual loss (3.8 percent) in United States oat production of all oat diseases during 1950-61. The causal agent of this disease was discovered and named in 1951. In 1954, a cooperative program was initiated with the Illinois Experiment Station to discover sources of resistance to BYDV in oats and to incorporate such resistance into agronomically acceptable oat varieties. Marked progress has been achieved in attaining this objective. Moderate resistance to BYDV was discovered in the old oat variety Albion as a result of screening the entire World Oat Collection. Through an intensive and accelerated backcrossing and testing program, this valuable level of BYDV resistance has been incorporated into Clintland 60- and Minhafer-type varieties. These promising selections are the first of a series being developed in the USDA-Illinois program, and they represent the first agronomically desirable types possessing combined resistance to BYDV, crown rust, stem rust, and the smuts.

10. Transmission Studies on Yellow Dwarf. In studies in cooperation with the Cornell University Experiment Station on improvement of techniques for basic work on barley yellow dwarf virus (BYDV), the membrane-feeding method has not proved as useful with Rhopalosiphum padi as with Macrosiphum granarium for assay of BYDV in liquid extracts. Stretched Parafilm was found to be a better membrane than Silverlight for virus assay by both aphid species. The membrane-feeding method was more sensitive than the needle-injection method for routine assays. Preliminary tests on the possible multiplication of BYDV in its aphid vector were inconclusive largely because of poor survival of injected aphids.

11. Vector Specificity with Yellow Dwarf. In cooperative studies at the Cornell University Experiment Station on vector specificity of isolates of BYDV, specificity occurred when acquisition was by means of aphids feeding through membranes on liquid virus preparations, as had been found previously when acquisition was by feeding on leaves or by injection. Vector specificity of 3 previously described strains continued in all 6 comparative serial transmissions

made during 1962. Study of a system involving double infections by 2 vector-specific strains of BYDV and the apparent loss of specificity by 1 of the 2 virus strains showed that the interaction of the strains during simultaneous multiplication in the plant was more important for the loss of specificity than was the interaction of the strains within the aphid.

C. Culture-Physiology

1. Winter Hardiness. Seed source was found to influence the pre-emergence and seedling survival of Dubois winter oats in cooperative studies conducted at the Cornell University Experiment Station. A lot of foundation Dubois seed was divided and seeded at 11 locations in the United States. Significant differences in cold resistance of 5-day-old seedlings were observed among the different seed sources. There were slight differences among the seed sources when 14-day-old seedlings were frozen. In general, seed source did not influence cold resistance of 21- and 28-day-old plants. In only exceptional cases did seed source affect the relative survival of 4-week-old plants. It was concluded that the differences in cold resistance among the seed lots were probably due to differences in the nutrient reserves of the endosperm and/or embryo acquired from the parent plants grown at the different locations. No significant correlations could be found, however, between the content of N, P, K, Ca, Mg, or Fe in the seed from different locations and pre-emergence (or seedling) survival.

2. Host-Parasite Relationship. Studies conducted in cooperation with the Florida Experiment Station on the effect of the phytotoxin victorin on the nitrogen metabolism of oats indicated that toxin treatment has no effect on free and bound amino acids of resistant varieties nor does it affect the bound amino acid content of susceptible varieties. Victorin does, however, cause marked changes in the free amino acid metabolism of susceptible varieties; i.e., glutamine and valine increase, whereas alanine decreases. Valine synthesis increases with increasing toxin concentration. These trends are first observed after 4 hours of treatment and are very pronounced after 6, 8, and 10 hours of treatment. Since little is known about the synthesis of the branch chain amino acids, it was not possible to ascertain the role of increased valine production due to toxin treatment. The reduction in alanine indicates that alanine may play a role in increased respiration by a series of reactions in which pyruvate is synthesized through a transaminase system. Pyruvate, through a CO_2 fixation reaction, could increase malate synthesis, which is connected to the cytochromes through a malate dehydrogenase pathway.

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RICE BREEDING AND GENETICS, DISEASE,
VARIETAL EVALUATION, AND CULTURE AND PHYSIOLOGY
Crops Research Division, ARS

Problem. Rice in the United States is grown on about 1,747,000 acres with a total annual production of over three million tons. Rice is the principal crop in certain areas in Arkansas, California, Louisiana, Mississippi, and Texas where it is produced under a wide range of soil and climatic conditions. The demands of processors and consumers are diverse because of the many food products made with rice. Adapted varieties that meet the requirements of producers and consumers are needed for each ecological area. Basic knowledge is needed on the genetics of important plant characteristics and the reaction to disease causing organisms in order to develop adapted disease resistant varieties. Basic studies need to be conducted on host-parasite relations, physiological races of fungi causing rice diseases, and the nature of disease resistance in order to establish control measures for important rice diseases. Information on the factors associated with the milling, cooking, and processing characteristics of rice is required so that the breeding lines can be tested to determine suitability for release. In order to produce rice economically, knowledge of the response of rice to such environmental and cultural factors as submerged soil conditions, fertility level, seeding date, spacing of plants, light, and temperature of the air and water is needed.

PROGRAM

The Department has a continuing long-term program involving geneticists, pathologists, chemists, and physiologists engaged in basic and applied research to solve growers' problems and to develop varieties to meet demands of industry and consumers. Rice breeding research is conducted at Stuttgart, Arkansas, in cooperation with the Arkansas Agricultural Experiment Station; at Biggs, California, in cooperation with the California AES and the California Cooperative Rice Research Foundation, Inc.; at Baton Rouge and Crowley, Louisiana, in cooperation with the Louisiana AES; at Beaumont, Texas, in cooperation with the Texas AES and the Texas Rice Improvement Association; and at Beltsville, Maryland. Cooperative rice disease investigations are conducted at Stuttgart, Arkansas; Baton Rouge and Crowley, Louisiana; and Beaumont, Texas. Cooperative quality evaluation studies are conducted at Beaumont, Texas. Cooperative culture and physiology investigations are conducted at Biggs, California; Stuttgart, Arkansas; Crowley, Louisiana; and Beaumont, Texas. Breeding and disease investigations also include informal cooperation with several foreign governments and private foundations in Central and South America, and with the International Rice Research Institute in the Philippines.

Rice research is conducted under PL 480 project A7-CR-2 at the Central Rice Research Institute, Cuttack, India. This research is concerned with the nature and variability of resistance of rice to the blast fungus and in physiological specialization in this fungus.

The Federal scientific effort devoted to research in this area totals 9.5 professional man-years. This number includes 5.2 devoted to breeding and genetics; 2.0 to diseases; 1.0 to variety evaluation; 0.5 to physiology and culture; and 0.8 to program leadership.

PROGRESS

A. Breeding and Genetics

1. Uniform yield nurseries. Uniform yield nurseries are grown in Arkansas, Louisiana, Mississippi, and Texas. The nurseries are made up of the leading commercial varieties, a few varieties formerly grown in this area, and more promising experimental varieties that have been developed in the cooperative breeding program. The varieties are divided in six groups on the basis of grain type and maturity. This experiment makes it possible to test new varieties under a wide range of environmental conditions and provides information on the range of adaptation of new varieties that is useful in deciding whether or not a new variety should be released for commercial production. In addition to obtaining grain yield and the agronomic data, reaction to natural infection by diseases is recorded, and milling quality and kernel characteristics are determined under uniform procedures in the laboratory at Beaumont, Texas.

2. Selections with unique cooking characteristics. The Jojutla variety, an introduction from Mexico, has unique cooking and processing characteristics which makes it a desirable type for canning. These characteristics are associated with a high amylose content and high positive setbacks from amylograph tests. This variety was crossed with Bluebonnet 50 and Century Patna 231 at Beaumont, Texas. Approximately 47 selections from these crosses were grown in 1962. Many of these selections had the Jojutla kernel characteristics and they matured early, but none had satisfactory plant types. Increase blocks of a number of the selections were grown so that 20 or more pounds of rough rice is available for quality studies. The more promising selections have been crossed back to Bluebonnet 50 and the F_1 plants of several of the new crosses will be backcrossed to Bluebonnet 50 in an attempt to

obtain satisfactory plant types. Careful quality evaluation tests will be required to make certain that the Jojutla cooking behavior is retained in backcross hybrids.

3. New varieties released. Two new varieties that were developed in the cooperative rice breeding program in Arkansas were increased in 1962 and released for production in 1963. These varieties are Nova and Vegold.

Nova, an early maturing, medium-grain variety was selected from the cross Lacrosse x Zenith-Nira. It has slightly higher lodging resistance, matures about four days earlier, and produces somewhat higher grain yields than Nato, the leading variety in this class. Nova kernels are slightly larger and less chalky than those of Nato. However, the milling yields of Nova, in percent, are less than for Nato so that the yields of head rice in pounds per acre are about equal for the two varieties. The processing and cooking characteristics of Nova and Nato are similar. Nova is resistant to hoja blanca disease; whereas Nato is susceptible. Under Arkansas conditions Nova has shown a much higher degree of resistance to blast than Nato and the two varieties react similarly to straighthead.

Vegold is a very short-season, long-grain variety derived from a multiple hybrid. The original cross was made at the Beaumont, Texas station and the F_2 and subsequent generations were grown at Stuttgart, Arkansas. Parent varieties included Hill selection, Texas Patna, Rexoro, and Supreme Blue Rose. Vegold is considered a special-purpose variety for seeding in June. It is recommended for seeding June 1 to 10 in northern Arkansas, June 1 to 20 in central Arkansas, and June 1 to 25 in the southern part of the state. Vegold matures about 4 days later, but is more lodging resistant, yields about the same amount of grain per acre, and produces higher head rice yields than Belle Patna. Because of its short growing season, Vegold, like Belle Patna, requires careful management of irrigation water. Also the proper timing of nitrogen fertilization is very important.

4. Inheritance of blast resistance. The mode of inheritance of reaction to races 1 and 6 of the blast fungus (*Piricularia oryzae*) was studied in Arkansas, Louisiana, and Texas. Zenith is susceptible to race 1 and resistant to race 6. Nato is resistant to race 1 and susceptible to race 6. These two varieties were crossed and it was found that F_1 plants were resistant to both race 1 and race 6 and that segregation occurred in F_2 so that nine phenotypic classes were observed in F_3 . Although further tests will be needed to confirm these results, these preliminary trials indicate that

reaction to each race is conditioned by independent genes, with resistance dominant. When similar information is available on the mode of inheritance of reaction to all races of the blast fungus, the possibility of breeding varieties resistant to all races will be greatly enhanced.

5. Low temperature tolerance. Low temperatures are not uncommon at seeding time and in late fall, so cold tolerant varieties are needed for all areas where rice is grown in the United States. This situation is amplified by the low temperature of the irrigation water in large areas in California and locally in other areas. The reaction of varieties to cold water is difficult to study in the field because of the variability of the water temperature within rather small areas. Preliminary trials conducted under controlled conditions at Beltsville, Maryland have demonstrated significant varietal differences in germination and seedling development in cold (60°F) water. This method will be used to test breeding lines.

6. New introductions. A total of 438 new introductions were received in 1962, grown in the greenhouse at Beltsville, Maryland and sent to one of the rice experiment stations for observation and testing in 1963. This material included entries from countries that are cooperating in the F.A.O. Uniform Blast Nursery, a group of varieties from Taiwan that are reported to be resistant to blast in that country, the varieties used to differentiate races of blast in Japan and Taiwan, a group of varieties and hybrids from Italy, a group of long-grain bulk hybrid populations from Surinam, and miscellaneous varieties from other sources. Introductions received before 1962 were grown at the rice experiment stations in Arkansas, California, Louisiana, and Texas in 1962.

7. Breeders' seed. Breeders' seed of recommended varieties was produced in Arkansas, California, Louisiana, and Texas.

B. Diseases

1. Blast. The International Blast Nursery, Western Hemisphere, of 116 entries was grown by cooperators in El Salvador, Guatemala, Nicaragua, Costa Rica, Colombia, and Argentina in Latin America, in The Philippines and India in Asia and in Arkansas, Louisiana, and Texas in U.S.A. Most of the varieties used to differentiate races of the blast fungus along with many experimental varieties were included. This test gives an indication of the races prevalent in each area and shows the reaction to blast of the experimental varieties under these different situations. Differential varietal reaction was observed in some of the nurseries.

Blast specimens are collected in farm fields in the Southern rice area each year in order to determine the races of the causal fungus. In 1961 a fairly large number of specimens were collected. These were isolated and identified in 1962. Of the 54 specimens that were collected and identified as to race of the fungus, six were race 1, twenty-four were race 3, twenty-one were race 6, one was race 7, one was race 10, and one was race 16. The predominant races 3 and 6 are closely related and are separated with difficulty by Lacrosse.

Many breeding lines are tested for blast reaction in the greenhouse. Races 1 and 6 are the key races used in this program. Race 1 was formerly quite prevalent. Zenith and many lines from Zenith crosses are susceptible. Race 6 has been prevalent in recent years. Nato and many lines from Nato crosses are susceptible to this race.

Blast is being studied under PL 480 project number A7-CR-2 at the Central Rice Research Institute, Cuttack, India. Most of the U. S. varieties in the World Collection, and the varieties in the International Blast Nursery were tested. The results indicate that the prevalent race or races at this location are different than those occurring commonly in the United States.

2. Seed treatment. Studies designed to develop treatments to control seedling blight and root maggots were conducted at Beaumont, Texas in cooperation with the station entomologist. Many of the combinations of fungicides and insecticides were effective in improving plant stands and reducing the number of maggots. In general, the chemicals applied to the seed as a slurry were more effective than the chemicals in liquid form.

3. Hoja blanca. The hoja blanca vector was found in rice fields in seven parishes in Louisiana, in 1962. Repeated surveys of infested fields failed to reveal any plants with hoja blanca symptoms. It was assumed that this infestation was a reintroduction of the insect and the insects introduced were non-viruliferous.

Host range studies of hoja blanca were conducted in Louisiana. The commonly grown cereals, sugar cane, and pasture grasses were tested. Typical hoja blanca symptoms were observed only on wheat, rye, barley, and oats of the 25 species that were inoculated. Barnyard grass (Echinochloa colonum) has been reported to be susceptible to hoja blanca but it was not infected in these studies.

Reaction to the hoja blanca virus of breeding lines was studied in the field in Latin America and in the greenhouse at Baton Rouge, Louisiana. The availability now of a strain of the vector that has a high percentage of transmitters makes possible the more efficient testing of breeding lines in the greenhouse.

4. Straighthead. A test to determine the reaction of breeding lines and new introductions was conducted near Eagle Lake, Texas. Many breeding lines were resistant, although most of the new introductions were susceptible. Known sources of resistance to this disease have been available for some time so that resistance has been incorporated into most of the breeding stocks being used.

C. Variety evaluation

1. Quality of breeding lines. Evaluation of the cooking and processing characteristics of breeding lines developed in the cooperating breeding programs in Texas, Arkansas, Louisiana, Mississippi, and California was conducted in the rice quality laboratory at Beaumont, Texas. Large numbers of breeding lines are evaluated with the iodine-blue test, the alkali test, and the protein biuret test. On the basis of results from these preliminary tests, the better lines are evaluated with the quantitative amylose test, the water uptake test, the amylograph, and the Kjeldahl protein test. In addition to these chemical and physical tests, many samples were parboiled and tested for milling quality and water uptake and the percent dry matter loss during pressure canning was determined. Results from these tests makes it possible to eliminate undesirable types and to continue only those breeding lines that have the desired characteristics.

2. Protein content. A rather wide range in protein content among rice varieties was observed so research was conducted at Beaumont, Texas to develop a method to rapidly estimate this important characteristic. A rapid screening test was developed that provides an empirical estimate of the protein content of milled and brown rice. The test is based on the well known biuret reaction of protein. A high correlation between protein biuret values and Kjeldahl protein values was found.

3. Evaluation of varieties for canning. An objective method which aids in evaluating the pressure canning stability of parboiled rice varieties and selections was developed at Beaumont, Texas. The method is based on the percentage of dry matter lost during pressure canning of parboiled rice. In general, lowest dry matter losses were associated with clarity of broth, a minimum amount of

splitting and fraying of edges and ends, and firmness in texture when rated subjectively. The percentage dry matter loss test is simple, rapid, and requires a relatively small sample size. The test is particularly well suited as an aid in recognizing the superior canning characteristics of varieties such as Jojutla which, heretofore have been recognized by the more time-consuming amylograph procedure. It is recognized that dry matter loss alone cannot be used to fully evaluate a sample of rice as to its suitability for pressure canning so this test is used in conjunction with subjective methods to evaluate breeding lines.

4. Modification of amylograph. The amylograph is a valuable instrument in the variety evaluation program, but its use is limited because 100 minutes is required to run a single determination. In view of the important results obtained from the amylograph, a rapid method, which is a modification of the regular procedure was developed at Beaumont, Texas. The modification consists of starting the amylograph at a temperature of 60°C, rather than at 30°C, after which the amylograph curve is terminated without the completion of the cooling cycle. The rapid short-form amylograph procedure requires only 25 to 30 minutes for each determination. It is particularly useful for evaluating the pasting characteristics of the advanced selections grown in the uniform yield nurseries. Similar results with respect to peak viscosity and resistance of the paste to thinning on heating at 95°C are obtained by both procedures.

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ALFALFA CULTURE, BREEDING AND
GENETICS, DISEASES, AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. Alfalfa and alfalfa-grass mixtures grown for hay in the United States occupy approximately 29,000,000 acres, and provide more than 50 percent of the total hay required by livestock. This crop produces tremendous soil improvement benefits which increase yield and quality of many nonleguminous crops grown in rotation with alfalfa. In addition, there is increasing importance in the use of alfalfa strictly for pasture in association with grass under range conditions and on sites unsuited for cropping. Stand establishment, persistence, forage yield and quality of alfalfa are materially affected by cultural and harvest practices, harmful insects, diseases, and temperature and moisture stresses. Adapted varieties which are resistant to diseases and insects, and tolerant to temperature and moisture stresses of the respective geographical areas are needed for more efficient farm production. Also, there is need for accelerated effort on basic research dealing with breeding methods, genetics, cytology, pathology, and physiology. Fundamental physiological studies must give consideration to the metabolic processes and chemical composition of alfalfa, and how these are affected by management practices and environmental stresses.

PROGRAM

The Department has a continuing long-term program involving geneticists, pathologists, physiologists, and agronomists engaged in the development of improved alfalfa varieties and cultural practices to reduce feed costs, increase farm income, stabilize production, and improve the nation's soil resources. To attain these objectives, part of the research is devoted to fundamental studies dealing with the genetics, cytology, physiology, and diseases of alfalfa.

The main objectives are to develop (1) disease- and insect-resistant varieties for hay and pasture, with improved quality, persistence, yield and agronomic characteristics, and adaptation to specific climates, soils, and uses; (2) more effective breeding procedures; (3) information on physiological phenomena involved in cold, heat and drought tolerance, and environmental factors affecting quality of forage; and (4) better understanding of the effects of cultural practices on stand, persistence, yield and quantity of saponins, estrogens, and other chemical constituents which affect quality. Work at University Park, Pennsylvania, is in cooperation with the 12 Northeastern States. Research at other locations is in cooperation with the corresponding State experiment stations.

The Federal scientific effort devoted to research in this area totals 14.3 professional man-years. Of this number, 8.4 are devoted to breeding and genetics, 3.0 to diseases, 2.4 to culture-physiology, and 0.5 to program leadership.

A contract with the University of Perugia, Perugia, Italy, provides for developing lines of alfalfa resistant to Verticillium wilt. Its duration is for 5 years, 1962 - 1967, and involves P.L. 480 funds.

PROGRESS

A. Breeding and Genetics

1. Improved Ladak readied for testing. Kansas tests indicated that Ladak alfalfa yielded and survived better than Buffalo in some parts of the State. Because of its desirable characteristics, a breeding program was initiated in 1958 in Kansas to breed into Ladak resistance to the spotted alfalfa aphid, pea aphid, and bacterial wilt. Tests of the improved Ladak showed that seedling survival after spotted alfalfa aphid infestation increased from 3 percent for the original unselected Ladak to 35 percent for one cycle of selection and 77 percent for two cycles of selection. Decreases in injury scores were as striking as those for survival. Seedling survival after pea aphid infestation increased from 9 percent for Ladak to 20 percent for one cycle of selection and 53 percent for two cycles. Syn. 1 seed of a synthetic derived from 95 second-cycle selections was produced during 1962 for further testing. Each of the selections was resistant to pea- and spotted alfalfa-aphids and bacterial wilt.

2. New alfalfa breeding material released. Clone C89, one of the five parents of Lahontan, was released for use in breeding programs conducted by public and private agencies. This is the first time that USDA has made alfalfa clones available to industry for their breeding programs. C89 is highly resistant to the stem nematode and both known biotypes of the spotted alfalfa aphid. It is moderately resistant to bacterial wilt, the pea aphid and possibly the alfalfa seed chalcid. But, like Nemastan and other Turkistan alfalfas, C89 is susceptible to leaf and stem diseases. The insect phase of this work was in cooperation with the Entomology Research Division.

3. Sonora alfalfa released for Southwest. Sonora was developed in cooperation with the Arizona, California, and Nevada Agricultural Experiment Stations and the Entomology Research Division. Sonora is a winter-tender, spotted alfalfa aphid-resistant variety that produces more winter growth than Moapa. It has yielded as much as 10 percent more than Moapa in Arizona and southern California. Sonora has excellent seedling vigor and is less susceptible to downy mildew than Moapa or African.

4. Stem-nematode resistance found in Cherokee. In 1961, 71 plants in Cherokee were found to have seedling resistance to the stem nematode at Raleigh, N.C. Subsequent tests of their S₁ progenies showed that 22 of the 71 had a high degree of resistance. Seed of a synthetic consisting of resistant clones is now being produced for testing. Finding stem-nematode-resistant plants in Cherokee will reduce the time needed to develop adapted stem-nematode-resistant varieties for the Southeast. Resistant plants were identified with a filter paper doll seedling inoculation test. The same general procedure has also been used successfully at Logan, Utah.

5. Northern root-knot nematode resistance retained in backcrosses. In a breeding program at Reno, Nev., designed to combine resistance to bacterial wilt, stem nematodes, spotted alfalfa aphids, pea aphids, and northern root-knot nematodes, resistance to root-knot nematodes was retained in approximately 35 percent of the first backcross to the susceptible parent. Additional plants with resistance were identified in Vernal-like selections with resistance to leaf and stem diseases.

6. Sources of resistance to foliar diseases. At St. Paul, Minn., all plants of Medicago suffruticosa, M. dzhawakhetica, M. intertexta, M. glutinosa, and M. marina were highly resistant to common leafspot. Resistant plants were also found in the Teton, Rambler, and Vernal, in Flemish strains, and occasionally in Ranger, Ladak, and Narragansett.

Some alfalfa plants had tolerance to spring blackstem in the field, but resistance like that for common leafspot was not found. Differences in resistance appeared to be a matter of lesion size. More resistance was found in M. falcata than in M. sativa. The species M. dzhawakhetica, M. suffruticosa, and M. marina had considerable resistance in field and greenhouse tests. M. tunetana and a hybrid between M. sativa and M. dzhawakhetica appeared resistant in greenhouse tests.

Resistance to Pseudoplea leafspot was similar to that for spring blackstem with regard to lesion size. In the more resistant types, the lesions remained small and leaves green much longer than in susceptible types. In greenhouse screening, some plants from commercial varieties were resistant after repeated inoculations, but none of them has been progeny tested. Some plants of M. tunetana had considerable resistance to Pseudoplea leafspot.

7. Transfer of Phoma resistance from M. dzhawakhetica to diploid M. sativa appears successful. A cytological study of a diploid F₁ hybrid between M. sativa and M. dzhawakhetica at St. Paul, Minn., indicated considerable homology between the genomes of the two species. Also, about 4 to 8 seeds per 100 pollinations were obtained

when the hybrid was backcrossed to diploid M. sativa. The backcross progeny was normal in vigor and appearance and segregated for resistance to Phoma.

8. Selection for resistance to Verticillium wilt. Work was initiated at Perugia, Italy, with P.L. 480 funds to develop alfalfa lines resistant to Verticillium wilt for use in breeding United States alfalfas. Development of inoculation methods and testing of Medicago spp. furnished investigator have received principal attention to date. Verticillium wilt is a destructive disease of alfalfa in Europe which has not yet been observed in the United States.

9. Breeding for resistance to the potato leafhopper damage. At University Park, Pa., tests of nymphal development rates and nymphal viability of potato leafhopper indicated that small differences existed among plants for antibiosis reactions and that these differences were difficult to measure. A combined field and greenhouse test was developed which seemed to effectively and efficiently measure adult oviposition preferences, variation in hatchability and nymphal viability. This method consisted of placing alfalfa plants in early bud stage into an infested field of leafhoppers for 48 hours and then bringing the plants into a control chamber or cool greenhouse. After 20 days, individual plants were fumigated and the number of nymphs counted. Number of nymphs were adjusted for plant weight so as to give numbers in unit dry weight of top growth. This test appeared practical and economical for breeding programs. At Beltsville, Maryland, remnant seed lots representing 11 cycles of recurrent phenotypic selection were used to establish a field test to determine the effect of selection for resistance to leafhopper yellowing on population means and variances. Work at both locations is in cooperation with the Entomology Research Division.

10. Development of weevil-resistant alfalfa difficult. Alfalfa breeding work on resistance to the alfalfa weevil at Beltsville, Md., and Raleigh, N.C., supports the following conclusions:

- (a) Varieties do not differ appreciably in susceptibility to damage from the alfalfa weevil larvae.
- (b) Suitable resistance to larval feeding has not been found.
- (c) Alfalfa lines spaced in rows 3 to 4 feet apart differed in larval damage, but this appeared to be related mostly to differential oviposition.
- (d) Several plants from M. sativa var. gaetula and some from the cross M. sativa x M. falcata have been isolated which have resistance to oviposition. Also, lines with considerable M. falcata parentage were more resistant than those primarily of M. sativa parentage.
- (e) Clones selected for resistance to oviposition differ morphologically but most are small, procumbent plants with fine stems. Crosses have been made between the divergent clones to attempt transfer of

resistance to desirable plant types and to characterize the mechanism of resistance. These studies are in cooperation with ARS entomologists at Beltsville and State entomologists at Raleigh.

11. Polycross seed of 98 elite alfalfa clones produced for inter-regional study. Polycross seed of 98 alfalfa clones was produced at Logan, Utah, in 1961 and 1962 for studies designed to (1) determine some of the relationships between forage yield, seed yield and location of test, and (2) evaluate general combining ability. The clones were selected for resistance to common leafspot, blackstem caused by Ascochyta, and bacterial wilt during the last 12 years at University Park, Pa. Several cycles of backcrossing, selfing, and intermating were used. Polycross seed produced at Logan, Utah, is being used to establish performance tests at University Park, Pa., St. Paul, Minn., and Logan, Utah, and observational tests at several other locations.

12. Selection for low saponin. The saponin contents of 242 varieties, strains, and plant introductions were determined in the last 2 years at Logan, Utah. Flemish and Nemastan derivatives were consistently high and low, respectively, in saponin content. Two low saponin lines, P.I. 258,826 and P.I. 236,614, and four high saponin lines, M. dzhawakhetica, P.I. 255,179, P.I. 206,672, and P.I. 214,218, were selected for further study. These lines ranged from 1.10 to 3.78 percent saponin.

In another study, 6 tons each of Lahontan and Du Puits alfalfa hay were harvested and cured for a feeding trial in cooperation with Animal Disease and Parasite Research Division. The saponin contents of the Du Puits and Lahontan hays were 2.35 and 1.54 percent, respectively.

In 1959 a study of meals from forage grown at diverse locations, and from different cuttings and varieties, indicated the feasibility of altering saponin content of alfalfa by breeding.

13. Large reciprocal differences noted for seed and hay yields in Utah tests. A 3-year test was completed in Utah comparing reciprocals of single- and double-cross combinations of the five parent clones of Uinta. Reciprocal differences for seed and hay yields were large. In one cross, the seed yield of reciprocals differed by more than 500 pounds per acre. Reciprocal differences for seed yield were closely related to self-fertility, but this relationship was not apparent for hay yield. More research on the significance of reciprocal differences in alfalfa is needed. A year ago an unanticipated selfing problem was reported in an interregional study designed to evaluate the 91 two-clone combinations among 14 elite clones.

14. Accidental selfing causes overestimation of general combining ability. The major effect of accidental selfing on estimates of general and specific combining ability from diallel crosses was found to be an overestimate of the general combining ability component, according to research at Raleigh, N.C. Actual data from three 6-clone diallel crosses produced by hand pollination without emasculation revealed that overestimates from accidental selfing ranged from 40 to 218 percent. The degree of overestimation depended on the character measured. Selfing was reported a year ago to be also a problem in crosses produced by honeybees. These studies demonstrate the importance of taking precautions against selfing in alfalfa when genetic variances are to be estimated.

15. Procedure developed for estimating autotetraploid components of genetic variance. An optimum procedure for estimating autotetraploid components of genetic variance was developed at Raleigh, N.C. This procedure uses the partial diallel cross in conjunction with a parent-offspring regression and an estimate of total genetic variance from replicated clonally propagated parents. At Ithaca, New York, the estimation of genetic components from double crosses is being investigated. The development of procedures for estimating genetic variances which are applicable to alfalfa should lead to a better understanding of the types of gene action important in alfalfa populations and aid in the development of more efficient breeding methods.

16. Methods of Syn-1 seed production compared. The Syn-1 generation of A224 and of A239 was produced by each of four methods: S₁, single-cross, doublecross, and multicross. Each Syn-1 was advanced to the Syn-2. Two-year data were obtained and analyzed with the following results: Differences due to method of Syn-1 seed production were significant (a) in the Syn-1 performances of A224 and A239 for forage yield, spring growth habit, fall growth habit, and rate of recovery; (b) in the Syn-2 performance of A224 for forage yield, spring growth habit, fall growth habit, and rate of recovery, and of A239 for fall growth habit; and (c) in the Syn-1 versus Syn-2 performance of A224 for forage yield, spring growth habit, fall growth habit, and rate of recovery, and of A239 for fall growth habit and rate of recovery. Cost was a major consideration in determining the best method of Syn-1 seed production. This work was done at Lincoln, Nebr.

17. Genetic characteristics of root-creeping character. Data from a six-clone diallel cross among root-spreading clones at University Park, Pa., were analyzed for general and specific combining ability effects on percent root-creepers and root-creep score at 1 year of age. Estimated components of variance for overall root-spread score and percent of root-spreaders were 2.68 and 5.24 times as large for general combining ability as for specific combining ability. The estimated component of variance for specific combining ability for score of the root-spreading fraction of the population, however, was

2.57 times that for general combining ability. Percentage of root-spreaders in the 15 crosses after 3 years averaged 70.7 as compared to 24.2 for Rambler. Percentage of spreaders in the 15 crosses after 1 year was highly correlated with percentage of spreaders after 3 years ($r = 0.866^{**}$).

18. Correlations between seed yield and other characters in alfalfa. At Reno, Nev., 1962 open-pollination seed yields of 113 clones planted on 4-foot centers in 1961 were correlated with 1961 seed yields ($r = 0.81^{**}$), plant vigor at seed harvest (0.64^{**}), open-pollinated percent pod set (0.233^{*}), percent pod set upon selfing (0.106), number of seeds per pod set upon selfing (0.179), estimated pollen production (0.212^{*}), and number of selfed seeds per 100 florets tripped (0.240^{*}). The correlation between pollen production and number of selfed seeds per 100 florets was 0.133 and that between percent pod set upon selfing and number of seeds per pod from selfing was 0.363^{**} . The 1962 seed yields of individual genotypes ranged from 194 to 1,625 pounds per acre and averaged 765. Seed yields on clones in 1961, the year of establishment, ranged from 12 to 194 pounds per acre and averaged 83.

19. Irregular transmission of satellite chromosome in alfalfa. Cytological observations on the behavior of the large satellite chromosome at St. Paul, Minn., supported genetic data indicating that the satellite chromosome was not transmitted through the male gamete. On the other hand, the rate of transmission through the female gamete was abnormally high. The controlling mechanism has not been established.

20. Cell culture techniques adapted for genetic studies in alfalfa. Progress has been made in the use of cell culture techniques in alfalfa genetic studies at St. Paul, Minn. Callus was grown from the stem, root, germinating seed, cotyledon, hypocotyl, and flower petal of alfalfa. Callus derived from seedlings was more friable and faster growing than callus from stems. Intensive pigmentation was not obtained in callus from flower petals, but callus tissues from purple, yellow, and white flowers were different. A completely synthetic medium was adapted to replace the coconut milk supplement originally used, resulting in greater chromosome stability. Limited differentiation of shoots and roots from callus material was obtained through manipulation of the nutrients and auxins in the media. Once callus material was formed, growth rate increased if transferred to media without 2-4-D.

B. Diseases

1. Method refined for testing alfalfa for bacterial wilt resistance. At Beltsville, Md., the cotyledon inoculation technique for infecting 7-day-old seedlings with bacterial wilt reported in 1961 was refined and adapted for large-scale evaluation of seedlings. In the modified technique, cotyledons of 7-day-old seedlings are sprayed with a bacterial suspension. The tips of the wet cotyledons are clipped with a scissors and then sprayed again with bacterial inoculum. Seedlings are incubated 24 hours at high humidity and allowed to grow from 30 to 36 days. Then they are dug and each taproot is examined for internal discoloration.
2. Strains of *Rhizoctonia solani* differ in production of cell-disrupting enzymes. Strains of *Rhizoctonia solani* tested at Raleigh, N.C., on a given culture medium differed in the properties of polygalacturonate chain-splitting enzymes produced. There was also variation when a single isolate was cultured on different media. A pectin-trans-eliminase (PTE) was produced by one strain after prolonged culture (11 to 16 days) on media containing both pectin and sugar. The *Rhizoctonia* PTE degraded pectin more rapidly than polypectate. PTE was not produced on media containing pectin as sole carbon source.
3. Virus infection reduces seed and forage yield of alfalfa in the field. In Minnesota tests, two virus sources reduced seed yield of an alfalfa clone in the field by 15 and 23 percent in seven tests during three seasons. The same two viruses reduced forage yield of the first cutting by 26 and 31 percent in three tests during two seasons.
4. Incidence of virus infection in alfalfa being determined. Perennial legumes like alfalfa become infected and weakened by plant viruses. Twenty-three alfalfa fields in Minnesota and Iowa were sampled by collecting at random foliage of 100 plants from each field. Each sample was indexed on tester hosts at St. Paul, Minn. The percentage infection ranged from 0 to 64. Fifteen percent of the plants, on the average, were virus-infected. Further studies are underway to determine the relationship of variety, age of stand and location on incidence of virus infection in alfalfa.
5. Alfalfa root rot fungi compared. Like other forage legumes, alfalfa is frequently attacked by root rotting pathogens which weaken plants, reducing productivity and longevity of stands. Diseased plants often develop a brown to black internal necrosis of the taproot. Fungi isolated from diseased roots at University Park, Pa., included species of *Fusarium*, *Pythium*, and *Rhizoctonia*. Only *F. oxysporum* was moderately pathogenic to 2-to 3-month-old plants. *Pythium* and *Rhizoctonia* spp. were either slightly or non-pathogenic. Best infection occurred when plants were clipped frequently and were held

at a relatively high temperature. At Stoneville, Miss., resistance to root rotting fungi is being studied from the standpoint of increasing persistence of alfalfa.

C. Culture-Physiology

1. Factors affecting coumestrol content of alfalfa studied. A study of factors influencing the accumulation of coumestrol in alfalfa was initiated in controlled environmental chambers at College Station, S.D. The variables were temperature, nutrient level, light intensity, stage of growth, and plant part. This work was begun after completion of a nation-wide study dealing with the relative importance of years, locations, cuttings, varieties, stage of growth and their interactions on coumestrol content of alfalfa. In the broad experiment at seven locations, environmental sources of variation and stages of growth were the predominant causes of variation. For example, coumestrol content of alfalfa harvested at the 1/10-bloom stage, averaged over 2 years, 3 cuttings, and 5 varieties, ranged from 12 p.p.m. at Davis, Calif., and Logan, Utah, to 126 p.p.m. at Ames, Iowa. Also, it was shown that coumestrol content increased with stage of growth, reaching the highest level 25 days after full bloom. Coumestrol is a naturally occurring estrogen in alfalfa with physiological properties similar to those of the synthetic estrogen diethylstilbestrol.

2. Varieties differ in yield response to plant spacing. At Reno, Nev., statistical analysis of forage yield data from a row-spacing study of Lahontan, Ranger, Zia, and Nevada Syn. E grown in single-row plots spaced 14 inches and 24 inches apart and in multiple-row plots with close spacing showed that the entry x spacing interaction was significant. This interaction was due to the fact that Lahontan and Syn. E yielded more in 14-inch rows than at other spacings, and Ranger yielded highest in multiple-row plots. Results were contrary to expectations. Lahontan had been expected to yield less than the wider crowned Ranger at wider row-spacings.

3. Ladak alfalfa performs well in dryland pastures. Ladak appeared to be the best all-purpose dryland alfalfa tested and suited for hay or dryland management with grass mixtures for most of the western region where alfalfa is grown. Tests were conducted in North Dakota, South Dakota, Nebraska, Kansas, Utah, California, and Oregon. Nomad was less well adapted but performed well under some conditions. The new varieties Rambler and Teton were persistent in Dakota tests, where winter hardiness was important, but required more testing. The results of these tests were summarized at Logan, Utah.

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CLOVER AND OTHER LEGUMES, CULTURE,
BREEDING AND GENETICS, DISEASE AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. A total of 45 species of clover, trefoil, lespedeza, vetch, lupines and other legumes are of regional or national importance in the United States. A great many other species of legumes are potentially valuable for pasture and land cover, provided adapted varieties can be developed. One or more kinds of these legumes are grown on 95 percent of the farms or ranches either for hay, pasture, silage, soil improvement, conservation, or for multiple uses. Losses due to diseases, insects, unfavorable climatic conditions, and undesirable plant characteristics, all associated with deficiencies in the present varieties, reduce farm values of these legumes by 50 percent. Improvement by breeding for winterhardiness and heat tolerance, drought resistance, disease and insect resistance, high yielding capacity, improved quality and palatability, freedom from toxic plant constituents, ease of establishment, stronger perenniality, tolerance of grass competition and of unfavorable soil conditions can be realized through basic and applied research. Long-lived, productive legumes are needed for the less fertile, poorly drained soils and for lands difficult to cultivate because of the rough terrain and associated erosion problems. Studies of cytogenetics, interspecific hybridization and methods of breeding; of diseases, including causal organisms and methods of control; and of physiological responses of plants to environmental factors and composition are essential to solving improvement problems. Domestic and foreign species and varieties for different uses throughout the United States must be evaluated.

PROGRAM

The Department has a continuing long-term program involving agronomists and plant breeders, geneticists, pathologists, and physiologists engaged in both basic studies and the application of known principles to the solution of farmers' problems. Basic and applied plant breeding research is conducted with red clover at Madison, Wisconsin, and Beltsville, Maryland; with sweetclover at Lincoln, Nebraska, and Madison, Wisconsin; with crimson clover at State College, Mississippi; with white clover at Clemson, South Carolina; with perennial clovers for irrigated high mountain valleys of the West at Fort Collins, Colorado; and with winter annual clovers at Beaumont, Texas. Basic genetic and cytogenetic investigations are conducted with red clover at Madison, Wisconsin; with sweetclover at Lincoln, Nebraska; with white clover at Clemson, South Carolina; and with perennial and native clovers at Fort Collins, Colorado.

Basic and applied research on the pathology of perennial clovers is in progress at University Park, Pennsylvania; Durham, New Hampshire; and Beltsville, Maryland. Basic physiological research is conducted on red clover at Lexington, Kentucky, and on white clover at Clemson, South Carolina. Cultural and applied physiological investigations of crimson clover are in progress at State College, Mississippi.

State Experiment Station programs cooperative with the Department include breeding, genetics, and cytogenetics of red clover at Lexington, Kentucky; breeding of white clover at Durham, New Hampshire; biochemistry of sweetclovers at Lincoln, Nebraska; and pathology of white clover at Clemson, South Carolina and of perennial clovers at Madison, Wisconsin. Cooperative work is also conducted with the Entomology Research Division of the Department in sweetclover improvement at Lincoln, Nebraska and Madison, Wisconsin.

Annual and perennial lespedeza breeding, disease and variety evaluation research is being conducted at Raleigh, North Carolina, in cooperation with the North Carolina Agricultural Experiment Station and at Beltsville, Maryland. Trefoil breeding and cytogenetic research is conducted at Ithaca, New York; breeding and disease research at Columbia, Missouri and Blacksburg, Virginia, in cooperation with the respective experiment stations and at Beltsville, Maryland. Trefoil disease research is also underway at Stoneville, Mississippi, in cooperation with the Mississippi Agricultural Experiment Station. Cultural (physiological) research with trefoil, lespedeza, crownvetch and tickclover is underway at Experiment, Georgia, in cooperation with the Georgia Agricultural Experiment Station. Lupine and tickclover breeding and disease and evaluation research is being conducted at Tifton, Georgia, in cooperation with the Georgia Agricultural Experiment Station. Crownvetch breeding research is conducted at Beltsville, Maryland.

The Federal scientific effort devoted to research in this area totals 20.7 professional man-years. Of this number 9.4 is devoted to breeding and genetics, 4.4 to diseases, 0.7 to variety evaluation, 3.7 to culture and physiology, 1.2 to plant introduction and evaluation, and 1.3 to program leadership.

A contract with the Ministry of Agriculture, Finland, provides for the intensification of polyploidy breeding in clover species. Its duration is for 5 years, 1961-66, and involves P.L. 480 funds with a \$19,457.00 equivalent in Finmarks. The basic part of this work concerns the possible improvement of seed setting abilities of tetraploid clovers; the tetraploid red and alsike clovers developed in such a program may be of value to Alaskan agriculture.

A contract with the Department of Plant Physiology, Warsaw, Poland, provides for a study of the metabolism of alkaloids in lupines and

the physiological role of these compounds. Its duration is for 5 years, 1961-66, and involves P.L. 480 funds with a \$17,791.00 equivalent in Polish Zlotys.

A contract with the Department of Genetics and Biochemical Laboratory, Poznan, Poland, provides for a study of the forms of nitrogen in species and varieties of legumes. Its duration is for 5 years, 1961-66, and involves P.L. 480 funds with a \$17,318.00 equivalent in Polish Zlotys.

A contract with the IBEC Research Instituto, Sao Paulo, Brazil, provides for the collection and evaluation of tropical and sub-tropical legumes of indigencus and world origin. Its duration is for 5 years, November 1961-66, and involves P.L. 480 funds with a \$94,610.00 equivalent in Brazilian Cruzeiros.

A contract with the Instituto "Jaime Ferron" de Microbiologia, Madrid, Spain, provides for a study of the virus diseases of leguminous plants. Its duration is for 3 years, 1961-64, and involves P.L. 480 funds with a \$18,153.00 equivalent in Spanish Pesetas.

PROGRESS

A. Breeding and Genetics

1. Red clover. Synthetic varieties, formulated on the basis of previously accumulated persistence and disease resistance data, were superior in Wisconsin in 1962 to best released varieties for plant stands in the third harvest year and forage yields in the second harvest year, and were superior to Dollard and equal to Lakeland in seed yields in the first harvest year. Research in Maryland indicated that relatively high temperature (90°F) increased pseudo-self-compatibilities of clones previously selected for either low or high pseudo-self-compatibility under greenhouse conditions, thus suggesting that self-incompatibility of red clover might be circumvented by temperature treatments during and subsequent to pollination.

In the P.L. 480 project on intensification of polyploidy breeding of clover species in Finland, plants of established tetraploid JoTPA1 and Ulva red clovers and JoTAA4 alsike clover were selected on the basis of previous seed setting abilities and agronomic merit as a prerequisite to synthesis of new tetraploid varieties. Newly derived tetraploids from the diploid Hakanen and Jokioinen red clovers were similarly screened prior to proposed synthesis of new tetraploid varieties.

2. Sweetclover. The breeding program in Nebraska included selection

for low-coumarin, aphid-resistant, large-seeded sweetclovers. In cooperative biochemical studies, an improvement was made in a rapid, qualitative paper test for coumarin, thus giving a better test for genotypes concerned with coumarin production. Variation in melilotic, o-coumaric, and coumarinic acids was attributed to years of growth, seasonal changes, plant parts (leaves, stems, roots), and genotypes (Cu B loci). No new mutations for low coumarin were discovered among a small number of plants surviving a previous seed X-ray treatment of 60,000 r. A discrepancy in previous segregation ratios for an albinistic character in M. officinalis controlled by a single gene was explained by shattering of shriveled seed, containing a disproportion of albinos, before harvest. Cooperative studies with Entomology Research Branch disclosed no resistance to sweetclover weevil within Melilotus species, but two species of a closely related genus, Trigonella foenum-graecum and T. gladiata, were repulsive (but non-toxic) to the insect. Seed production of Denta sweetclover within plastic mesh cages in Wisconsin declined sharply with reduction in light due to increased density of mesh.

3. Crimson clover. Frontier, a new variety of crimson clover exhibiting greater seedling vigor and fall and winter growth, was released in Mississippi. Inbred lines of the species varied greatly for seed yield and quality, plant maturity, morphology, and vigor, and combining ability. Inbred lines performed similarly in seeded rows, broadcast plots, or spaced-plant rows. Selfing has isolated lines exhibiting various flower colors and also a self-sterility character. Resistance to sooty blotch, Cymadothea trifolii, was found.

4. White clover. Frequent branching of stolons was shown to be a desirable selection criterion in work at Clemson, South Carolina for breeding programs. Variation among clones was found for reaction to stolon rot caused by Fusarium roseum and for reaction to root knot nematode, Meloidogyne incognita. Syn 2 seed of a 6-clone synthetic was produced and used throughout the Southern States in establishment of evaluation trials.

5. Winter annual clovers. Selections of Persian (T. resupinatum), Berseem (T. alexandrinum), and ball (T. nigrescens) clovers were superior for resistance to damage by freezing and for forage production at low temperatures at Beaumont, Texas. A selection of Persian, for which release is contemplated, was superior to common Persian in forage and seed yields, resistance to plant lodging and seed shattering, and early fall and late spring grazing. Eight generations of selection increased hard seed from 1/2 to 63 percent for this selection of Persian clover.

6. Perennial clovers. Differences in self-compatibility existed

between diploid and tetraploid strains of alsike clover at Fort Collins, Colorado but not among strains within each level of ploidy. The frequencies of highly self-incompatible diploid and tetraploid plants were 63 and 31 percent. Cross-compatibility relationships among 9 zigzag (T. medium) plants indicated some intra-sterile, inter-fertile groupings, suggestive of oppositional alleles.

7. Annual lespedeza. Four F₅ lines of Korean lespedeza developed in the cooperative program at Raleigh, North Carolina, are being increased for further testing. These represent the best of a large number of lines selected for superior yield and resistant to tar spot and root knot nematodes. The 4 lines have light pink flowers in contrast to the usual darker purplish color, which provides a simple means of identification. Forage and seed yields of these (4 lines) are at least greater than varieties in current use. Approximately 10,000 pounds of foundation seed of Summit lespedeza, developed in the cooperative program at Missouri and Arkansas, are available for planting in 1963. In the western part of the lespedeza region, Summit is 8 days later and produces 30 percent more forage and seed and is more resistant to tar spot and wilt than Korean lespedeza.

8. Trefoil. Birdsfoot trefoil is a long-lived, non-bloating perennial legume adapted to poorly drained soils as a permanent pasture legume. The present varieties are long-lived only in the more northern latitudes and in the Appalachian Highlands of Virginia, West Virginia, North Carolina, and Tennessee. In the cooperative breeding program at Ithaca, New York, and at Blacksburg, Virginia, the polycross method of breeding is being explored as a means of developing superior varieties. In the New York program, 4 years of progeny testing has resulted in the selection and establishment of superior clones for the production of synthetic varieties. Fourteen clones have been selected and recombined in the 9 synthetics for cage production of Syn 1 seed. These clones were combined on the basis of superior progeny performance for yield, establishment, seed set, persistence, winterhardiness, and tolerance to root rots. All possible single crosses between clones within each synthetic have been produced in order to evaluate the specific combining ability of each clone and methods for producing synthetics. In the Virginia program, as a result of progeny testing plants in a polycross, 10 clones superior in all respects have been selected for the production of a new synthetic. Syn 2 seed of this synthetic was produced in 1962 and is being evaluated in a number of yield tests. The use of inbreeding, followed by selection of hybridization is being explored as a method of developing superior varieties of trefoil in the New York program. S₄ and S₅ progenies are being evaluated for persistence, root rot tolerance and other characters. Persistent plants will be evaluated for general and specific combining ability. A 25 percent reduction in yield occurred in progenies

of crosses between more closely related S_2 plants (plants having the same S_0 and S_1 parents) as compared to progenies of crosses between unrelated S_2 plants.

In other areas the susceptibility of birdsfoot trefoil to a complex of crown and root rotting organisms results in short-lived stands, thus limiting the use of this important pasture legume. Studies are underway in the cooperative program at Columbia, Mo.; Stoneville, Miss.; Beltsville, Md.; and at Charlotte Court House, Va., to obtain lines carrying resistance to root rots. In these studies, clones exhibiting some root rot resistance are entered into a recurrent phenotypic selection program in an effort to increase genes for resistance to root rot. Second cycle results at Columbia, Mo. and at Beltsville, Md. indicate that progress is being made in securing more resistant stocks. Two synthetics are being evaluated in yield tests at present. Efforts are being made to develop improved varieties of big trefoil in cooperative programs at Blacksburg, Va.; Stoneville, Miss.; Tifton, Ga.; and at Beltsville, Md. At Tifton, Ga., Sclerotium rolfsii and Rhizoctonia solani and the latter disease at Stoneville, Miss., seriously reduce stands of big trefoil. Positive resistance to either disease has not yet been found in any of the material available for study. At the more northern locations, a number of the tetraploid lines of big trefoil appear quite promising and it should be possible to develop more resistant strains less affected by Rhizoctonia solani.

9. Lupine. Blue and yellow lupines are potentially valuable legumes for winter grazing, forage, and/or soil improvement in the Southeastern States, provided productive, sweet, disease-resistant, and winter-hardy varieties are developed. A new blue lupine sweet strain, 60-206, carrying resistance to anthracnose and Stemphylium, and genetically marked for ease of identification, was found to be more productive for forage and seed than other sweet forage varieties in yield tests at Tifton, Ga. As soon as sufficient seed stocks of 60-206 are accumulated, it will be named and released for farm use.

The unusually severe winter of 1962-63 at Tifton, Ga., provided conditions whereby segregating blue lupine populations could be effectively evaluated for winterhardiness. Common varieties were winter-killed 100 percent by the low temperature of 6°F. in December 1962, whereas no plants of the hardy strain WH-1 were lost. WH-1 is bitter, hard-seeded and susceptible to anthracnose. At the end of the winter 51 percent of the plants of WH-1 were killed. All of the F_1 plants having WH-1 as one parent and all but 6 percent of 31,429 F_2 plants were dead. The surviving F_2 lines will be screened in a search for plants homozygous for winterhardiness, resistance to anthracnose, Stemphylium, sweetness, and soft seededness. The possibility of securing a number of lines having all of the desired characteristics

appear to be very good.

10. Sericea lespedeza. Sericea is a well adapted perennial legume for southeastern soils where it is used for hay and soil improvement. While good quality sericea hay is reasonably satisfactory for animal maintenance, its digestibility is low. Digestibility trials indicate that the low digestibility is due to the high tannin and lignin content in sericea forage. In general, animal gains on sericea pasture have not been satisfactory, due also to the high amounts of tannin and possibly lignin in the green plant. Progress is being made in the cooperative program at Raleigh, N. C., in the breeding and development of new strains of sericea containing significantly less tannin and lignin. Analyses of high and low tannin plants show low tannin plants to also be lower in lignin. A composite strain of low to moderately low tannin plants will be evaluated for intake and digestibility in the North Carolina program.

11. Tick clovers (Desmodium sp.). The objective of the studies on the tick clover species is to develop a perennial legume for forage production and compatible in association with summer-growing grasses such as bahia- and bermudagrass. Nineteen of 75 such accessions were found to be perennial. These 19 were planted together in an area for palatability studies. Desmodium heterocarpum was most palatable and appears to have promise for pasture. The work is continuing. Limited studies are being continued on perennial peanuts and crownvetch in an effort to develop better perennial forage legumes.

B. Diseases

1. Phyllody virus infection stimulates rooting in clover flower heads. Flower heads from phyllody-diseased Ladino and alsike clovers rooted when they were placed on soil at Beltsville, Md. The resulting plantlets did not originate from seed in the flower head but were vegetative propagules of the mother plant. Flower heads from healthy clover plants fail to root when similarly treated. Transformation of floral parts into vegetative structures in phyllody-diseased plants is probably accomplished by virus interference with normal growth-regulator response. The drastic effect permits vegetative propagation and multiplication of phyllod plants which otherwise would be difficult or impossible.

2. Root rot most severe when red clover is exposed to insect-fungus combination. Cooperative entomology-plant pathology investigations at University Park, Pa., showed that Calomycterus setarius larvae feed on small rootlets of red clover and when full-grown, gouge tap and lateral roots. When soil was infested with C. setarius alone,

with Fusarium spp. alone and a combination of the insect and Fusarium spp., most root rot developed in red clover exposed to the combination treatment.

3. Older leaves of white clover more susceptible than younger leaves to foliar diseases. When different aged leaves of white clover were inoculated with cultures of the pepper spot fungus (Pseudosphaerulina trifolii) and leaves of red clover were inoculated with the target spot fungus (Stemphylium sarcinaeforme), older mature leaves were more susceptible than younger leaves. The research, conducted in New Hampshire, determined that varietal differences occurred in response of red clover to target spot infection. This suggests that selection for resistance is possible.

4. Virus-free seed of sweet yellow lupine produced. Cooperative research with ARS entomologists at Tifton, Ga., has resulted in production of approximately 1600 pounds of bean yellow mosaic virus (BYMV) -free seed of Weiko III yellow lupine. This seed-borne virus was largely responsible for reducing the acreage of sweet yellow lupine in the southeastern United States from a peak of 200,000 acres in the late 1940's to less than 1,000 acres in 1962. The recommended procedure includes delaying planting until after a hard freeze. A systemic insecticide (phorate) is then applied at two pounds of the active ingredient per acre in an 8-inch band over lupine rows 36 inches apart. Three insecticide applications are made during the period January 1 to March 15. During this period any virus-infected plants observed are rogued and destroyed. If the seed production system proves economical, a substantial part of the acreage formerly planted to sweet yellow lupine may be restored.

5. Soybean purple stain fungus causes disease of guar. A species of Cercospora isolated from lesions on guar stems and from purple-stained guar seeds at Stoneville, Miss., proved to be identical to C. kikuchii which induces purple stain of soybean seeds. Isolates of the fungus from guar caused purple discoloration of soybean seed. Conversely, inoculation with isolates from soybean produced foliar symptoms on guar and discoloration of guar seeds. The fungus also induced lesions on seedling leaves and stems of two species of Psoralea.

6. Sclerotium rolfsii destroys guar. Approximately 80 percent of a 1/8 acre test planting of guar at Tifton, Ga., was attacked and destroyed by the fungus Sclerotium rolfsii. The susceptibility of guar to this fungus suggests that plantings should not be made where S. rolfsii is prevalent.

7. Tar spot fungus life cycle completed under controlled conditions. At Raleigh, N. C., a method was developed for culturing the tar spot

fungus, Phyllachora lespedeza, on Lespedeza stipulacea and obtaining successive life cycles on plants indoors. Growth chamber studies suggested that the life cycle is completed only when temperature and light are favorable for host growth but that there is probably also a direct effect on the fungus. The life cycle was completed in 15 days under a 16-hour daylength at 75°F. daytime and 70°F. nighttime temperatures. Outdoors the life cycle is completed in 19-21 days. Occurrence of the stromatic body appeared to be correlated with advanced maturity of host tissues rather than in response to external environment.

8. Lespedeza cuneata disease resistance may be associated with phenolic plant constituents. In experiments conducted in North Carolina high tannin lines of L. cuneata resisted infection by the soil and foliar blight fungus Rhizoctonia solani. Leucoanthocyanin from Rhizoctonia-resistant leaves inhibited cellulase and polygalacturonase enzymes of the fungus in vitro, indicating that inactivation of cell wall macerating enzymes may be a mechanism of resistance.

9. Desmodium species being evaluated for anthracnose resistance. A relatively low incidence of anthracnose carried in the seed of Desmodium sp. may cause extensive seedling losses. In the greenhouse test at Tifton, Ga., only 0.3 percent of the seed was infected, yet the fungus rapidly spread from infected seedlings to thickly seeded healthy neighboring seedlings, destroying a large proportion of the stand. The observation has facilitated testing seedlings for anthracnose resistance under controlled conditions. Lines that appeared resistant in 1961 were resistant in the field in 1962.

10. Diseases of trefoil. Preliminary studies conducted in controlled bioclimatic chambers indicate that high temperatures and frequent defoliation increase the susceptibility of trefoil plants to root rot in cooperative studies at Columbia, Mo. Comparative studies of seedling plants vs. rooted cuttings indicated that the latter were more susceptible to root rot. Rhizoctonia blight continues to be a major disease on big trefoil at Tifton, Ga. No real evidence of resistance has been found in this species.

11. Virus diseases of special legumes. Research under P.L. 480 project E25-CR-16 seeks to isolate and identify viruses occurring in leguminous hosts in Spain with particular reference to characterizing cell inclusions formed by specific viruses in different hosts. Histopathology of 8 viruses out of 66 samples collected has shown that the viruses can be separated into 3 main groups: (a) viruses associated with amorphous and crystalline cell inclusions which infect leguminous and solanaceous plants; (b) viruses with only amorphous cell inclusions which infect legumes but not solanaceous plants, and

(c) one virus without cell inclusions which infect both leguminous and solanaceous plants with a different symptomatology from other viruses tested.

C. Varietal Evaluation

1. Clovers. Evaluations of the Northern Great Plains Uniform Sweet-clover Nurseries were conducted at 14 locations in 4 States and in 2 provinces of Canada. Denta sweetclover, a low coumarin synthetic variety released in 1961, has shown some resistance to blackstem and gooseneck diseases, high forage yields, rapid recovery after clipping, and good adaptation to the Northern Great Plains. Lakeland and Dollard red clovers were superior for forage production in Wisconsin; seed production of Lakeland was superior to that of Dollard. All white clovers failed to survive the third summer of test at Beaumont, Texas, under conditions of extreme drought and high temperatures.

D. Culture - Physiology

1. Red clover. Investigations in Kentucky revealed no significant differences in rates of respiration, photosynthesis, or the P/R ratio among three groups of clones varying in persistence and degree of inbreeding, thus indicating no direct relationship between persistence and rates of respiration or photosynthesis.

2. White clover. Data of seven growth chamber experiments conducted in South Carolina showed no consistent correlations between total free sugar, sucrose, or maltose concentrations and frequency of branching, leaf production, or total plant production of white clovers. Different response patterns of sucrose and maltose indicated a temperature-induced shift in carbohydrate metabolism.

3. Crimson clover. Simulated early summer reseedling of crimson clover in a bermudagrass sod in Mississippi produced best stands and earliest growth in the fall at the heaviest seeding rate of 80 pounds per acre. Fall disking reduced both clover and grass yields. The ability of crimson clover plants to grow at lower temperatures was established as a selection criterion in the breeding program.

4. Tannins and forage quality in sericea lespedeza and tick clovers. Cooperative studies have shown that a tannin content of the leaves above 7 percent in sericea and certain species of the tick clovers inhibits the activity of the enzyme cellulase in the cooperative program at Experiment, Ga. Inhibition of cellulase activity results in lowered digestibility and a general reduction in nutritive value or the quality of the forage. Alfalfa and bermudagrass hay proved

to be excellent sources of cellulase for determining cellulase inhibition in the legumes. These plant cellulases have the same characteristics as free rumen cellulase and appear to be better suited than commercial cellulase for testing cellulase inhibition of potential forage legumes. Screening studies of the tick clovers (Desmodium spp.) indicated the annual species to be more palatable than the perennials.

5. Alkaloids in lupines. A more rapid test for alkaloids has been devised for screening large populations in the search for low alkaloid plants in the cooperative program at Experiment, Ga. The method has been mimeographed and released for use by plant breeders.

The accumulations and transformations in the alkaloids in lupines are being investigated under the P.L. 480 Project E21-CR-1 at Warsaw, Poland. The results show the greatest amounts of alkaloids to be in the side branches of the plant. Seventy to 90 percent of the alkaloids formed are synthesized in the side branches in white lupines. Once plants are mature, synthesis and the decomposition of alkaloids are inhibited.

6. Amino acids in legumes. A new amino acid, tingitanine, has been found in Lathyrus tingitanus in the research program at Poznan, Poland, under P.L. 480 Project E21-CR-10. Relatively large amounts of tingitanine are stored in the seed of this species. The studies indicate that this free amino acid plays an important role in the nitrogen metabolism of tangier peas. Growth studies show that tingitanine serves as a readily available source of nitrogen used in the germination and early growth of seedling plants. The studies on the free amino acids of forage legumes and grasses are being continued.

7. Brazilian legumes. Studies are underway to evaluate native and introduced legumes for forage in the State of Sao Paulo, Brazil, under P.L. 480 Project S3-CR-7. During the year, 500 species and strains of plants and seed were collected and established in field plantings. The primary objective of these investigations is to find a legume that would provide grazing during the dry winter months. Fifteen species of 6 genera, Centrosema, Desmodium, Dolichos, Phaseolus, Stylosanthes, and Vigna appear promising in preliminary studies.

E. Plant Introduction and Evaluation

Among the legumes, clovers including white, red, crimson, sweet, persian, alsike, and zig-sag are the subject of much basic and applied research. Introductions of red clover, Trifolium repens, and white clover, T. pratense, are receiving most attention among plant breeders and agronomists throughout the northeastern and central United States. The improvement of other clover species

through plant introductions is given in a few reports from widely scattered areas throughout the country. Red and white clovers are being evaluated for winter hardiness and disease resistance. Red clover introductions reported tolerant to powdery mildew and which exhibit winter hardiness include: 228365 (Iran), 234838 (Germany), 234957 (France), 235855 (Sweden), and 260250 (Germany).

Concentration on plant type and root-knot nematode resistance in white clover improvement is reported. A new variety of persian clover 'Gulf Persian' was released jointly by Texas A&M College and USDA. Examples of zig-zag clover, T. medium, introductions reported as being particularly outstanding in vigor, production, and disease resistance include P.I. 284621 (New Zealand), and P.I. 250989 and 253200 (Yugoslavia). Arrowleaf clover, T. vesiculosum, introductions are continuing to be evaluated in southeastern United States with variable results. One introduction, P.I. 233816 (Italy), is outstanding in seedling vigor and yield. A new variety of arrowleaf clover 'Amclo', recently released in Georgia, was derived from P.I. 234310 (Italy). The new crimson clover 'Frontier' recently jointly released by Mississippi Experiment Station and USDA was derived from P.I. 233812 (Italy). Soil Conservation Service reports from adaptation studies that six clover accessions survived -40°F temperature in Idaho tests; they include three white clovers; P.I. 224680 (England), 231786 (New Hampshire), 234678 (France); two red clovers; P.I. 234941 (Switzerland), 239700 (Switzerland); and one alsike; P.I. 257273 (Sweden).

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FORAGE GRASS AND TURF CULTURE,
BREEDING, DISEASES AND VARIETY EVALUATION
Crops Research Division, ARS

Problem: There are some 90 introduced and native grasses that are of agricultural importance in the United States for forage, turf, and soil conservation. Of these, only 25 are included in active research programs. A large proportion of new seedlings, probably 50 percent, are failures or near failures, and this staggering loss could be reduced materially with varieties characterized by improved seedling vigor, seedling drought tolerance, and disease resistance. Diseases reduce the yield and quality of forage and seed and contribute to the loss of established plantings grown for either forage or turf purposes. Hybridization offers much promise in improving disease resistance in dallisgrass, drought and disease tolerance in orchardgrass, and nutritive value in reed canarygrass and weeping lovegrass. Effective breeding work on grasses adapted to semiarid and arid conditions demands the development of seedling vigor, temperature extremes, and rooting characteristics. In most grasses, progress in developing improved varieties depends on the accumulation of basic information in the fields of cytology, genetics, pathology and physiology. Homeowners, business establishments, and managers of parks, cemeteries, and other turfgrass areas spend a minimum of three billion dollars annually in establishing and maintaining turf. Many management practices in use today are wasteful of seed, fertilizer, labor, and water, and frequently result in failure to establish or maintain satisfactory turf. Improved management practices and improved grass varieties are urgently needed to meet the different requirements of use, climate, and soil that characterize the major turfgrass regions of the United States.

PROGRAM

The Department has a continuing long-term program involving agronomists, geneticists and plant pathologists engaged in both basic and applied studies. Breeding, genetic and cytogenetic studies on the development of improved grass breeding methods and superior grass varieties for range reseeding, pasture, hay, and general purpose turf are in progress at Tucson, Arizona; Tifton, Georgia; Manhattan, Kansas; Lexington, Kentucky; Beltsville, Maryland; State College and Stoneville, Mississippi; Lincoln, Nebraska; Mandan, North Dakota; Stillwater and Woodward, Oklahoma; University Park, Pennsylvania; College Station, Texas; Logan, Utah; Madison, Wisconsin; and Laramie, Wyoming. Research on grass diseases are underway at Tifton, Georgia; Beltsville, Maryland; and Stoneville, Mississippi. Variety evaluation studies are conducted at Lexington, Kentucky; Beltsville, Maryland; State College, Mississippi; Lincoln, Nebraska; Mandan, North Dakota; Woodward, Oklahoma; Logan, Utah; Madison, Wisconsin and Laramie, Wyoming. Cultural

investigations are conducted at Tucson, Arizona; Tifton, Georgia; Beltsville, Maryland; State College, Mississippi; Lincoln, Nebraska; Mandan, North Dakota; Woodward, Oklahoma; Logan, Utah; and Laramie, Wyoming. All work is conducted in cooperation with the respective State Agricultural Experiment Station.

The Federal scientific effort devoted to research in this area totals 20.9 professional man-years. Of this number 13.0 are devoted to breeding and genetics, 0.7 to diseases, 1.3 to variety evaluation, 2.3 to cultural investigations, 3.2 to plant introduction and evaluation, and 0.4 to program leadership.

A contract with the Indian Agricultural Research Institute, New Delhi, India, for cataloguing and classifying genetic stocks of Pennisetum spp. Its duration is for 4 years, 1962-66. This project will benefit applied and basic research studies in the United States and India.

A contract with the Ministry of Agriculture for the State of Rio Grande do Sul, Brazil, for ecological and cytological studies and genetic improvement of forage grasses and legumes. This project, initiated in September, 1961, will be conducted over a period of 5 years. Exhaustive collections of major indigenous species and information on their cytogenetics and breeding behavior will benefit United States and Brazil.

PROGRESS

A. Breeding and genetics

1. Superior timothy synthetics from self-fertile parents. Selection for self-fertility has been used to advantage at Madison, Wisconsin, to develop superior timothy synthetics. Progenies from self-fertile plants occurring in populations from self-sterile individuals in the S₀ generation averaged 9 percent rust susceptible plants, compared with 16 percent in progenies from self-sterile plants. The percentage of rusted plants ranged from 13 to 20 percent in experimental synthetics T-1, T-4 and T-5 and the variety Drummond; while the range increased significantly to 36 to 96 percent in the varieties Essex, Milton, Climax, Lorain and Common. Stand development in mass-seedings at Madison and Marshfield, Wisconsin, have favored the experimental synthetics, and exceptionally high seedling vigor was observed in one of the synthetics (T-4) formed from self-fertile parents.

2. Sac smooth brome for the midwest. Breeding smooth brome for resistance to foliar diseases and soil borne organisms led to the development of the variety, 'Sac', at Madison, Wisconsin. This new variety was released in 1962 in cooperation with the Wisconsin Agricultural Experiment Station. Sac is characterized by seedling and foliage disease resistance, good vigor and very good seed-producing

characteristics. Its growth habit and foliage are similar to southern-type varieties, such as, Achenbach and Lincoln, while the seed is heavy and similar in appearance to that of northern varieties. Plants are strongly creeping and have moderately coarse leaves and stems. Although the yield potential of Sac approximates that of other improved varieties, forage quality is superior because of its resistance to foliage diseases. In Wisconsin, seedling vigor and establishment has surpassed that of other named varieties. The superior establishment and forage quality of Sac will improve the value of the smooth brome in alfalfa mixtures in Wisconsin and other North Central States.

3. Rapid advances in hybridizing Paspalum spp. At State College, Mississippi, large scale hybridization studies within Paspalum spp. have resulted in the production of some 50 interspecific hybrids and three backcrosses. These hybrids were isolated following the emasculation and pollination of 56,000 florets from 21 Paspalum spp. It was evident in these studies that the number of emasculations and pollinations contributed more to successful hybridization than did the careful selection of parents on the basis of chromosome number and morphology. Species hybrids varied widely in morphology, and no two F₁ hybrids from the same parents appeared the same. Dallisgrass and vaseygrass F₁'s were very small with a relatively normal vaseygrass-type panicle. On the other hand, the reciprocal hybrid exhibited considerable heterosis. In general, the use of P. notatum as a pollinator produced hybrids with purple and yellow leaves and a poorly developed root system. The F₂ progeny of the cross between P. notatum x P. dilatatum looked very promising, as 73 percent of the plants had a seed-set of 80 percent or more. F₃ selections from the higher seed-setting F₂'s averaged 10 percent higher seed-set. The breeding behavior and potential of these hybrids will be evaluated at State College, Mississippi, and in cooperative studies with the federally-supervised cytologist at College Station, Texas.

4. Improved quality and yield from bermudagrass hybrids. Several promising hybrids have been developed at Tifton, Georgia, by crossing the improved Coastal variety with two African introductions. In 1961, ten of the Coastal x Kenya F₁ hybrids yielded 64 percent more forage than the means of their two parents. These hybrids survived the winter and in 1962, an unusually dry year, performed well. The Kenya parent failed to survive the winter but Coastal and Coastal-Kenya hybrids 9, 11 and 14, yielded 4.76, 5.52, 5.35 and 4.40 tons of dry matter per acre in 1962. Respective leaf percentages of the forage harvested were 67, 62, 74 and 65 percent. The in vivo "digestibility" of the August harvest was 59.0, 47.9, 52.4 and 60.9 percent, respectively. Variations in yield, leaf percentage and digestibility, were interesting as hybrids 9, 11 and 14 were sister hybrids that were very similar in morphological appearance. At Watkinsville, Georgia, heavily fertilized and irrigated plots of Coastal and hybrids 5, 11 and 14 produced 4.37, 6.85, 7.85 and 6.76 tons of dry matter

per acre. These plots were planted on May 14 and harvested on October 29. Although rapid establishment of the hybrids was responsible for part of the increased production, it would appear that these matings will give hybrids that possess greater yield potential than Coastal bermudagrass.

5. Bluestems for conservation plantings. Pawnee and Champ big bluestem have been released for conservation and forage use in the Central Great Plains. The varieties were developed at Lincoln, Nebraska. Pawnee from collections made in Pawnee County, Nebraska, and Champ from prairie and sandhill sources (Cherry and Pawnee Counties, Nebraska and Ames, Iowa). Pawnee is typical of the big bluestems of the central prairies, having long dark-green leaves, tall stems and forked, green to purplish inflorescences. It will be recommended in the south-central and southeast districts for seed production, and for forage plantings in the northeast, east-central, southeast, central and south-central districts of Nebraska. Champ is a moderately late-maturing variety but ordinarily a week to ten days earlier in seed maturity than Pawnee. Plants are leafy and variable in awn length, culm and glume color and foliage color. Champ may be grown for seed in central and eastern Nebraska as far north as the central Platte and lower Loup and Elkhorn valleys. For conservation and forage use it may be utilized in solid stands and mixtures in the eastern two-thirds of Nebraska. Pawnee and Champ are superior to ordinary bluestem in seed set and seed quality. In addition, both varieties have performed well in a number of forage yield tests. Pawnee and Champ will be increased under a limited generation system, with foundation seed being made available to a limited number of seed growers in 1963.

6. Germination of intermediate wheatgrass at low temperatures. The ability of intermediate wheatgrass seed to germinate at low temperatures appears to be highly heritable, on the basis of tests conducted at Laramie, Wyoming. In 1960 open-pollinated seed of 20 clonal selections were germinated at 8°C. in the laboratory. The best 5 percent of the seedlings and the poorest 5 percent (based on germination) were selected from each of the 20 lines. Four of the high seedlings from each line were established in an isolated crossing block (80 plants), while a second crossing block contained four low seedlings from each of the lines. Seed from the four plants of each line in each block were bulked for subsequent germination tests at 8°C. Preliminary tests show that the germination percentage of progenies from the high block are on the average 100 percent higher than those from the low block. Progeny from high selections are showing increases as high as 800 percent over low selections of the same lines.

7. Self-fertility of crested wheatgrass. If the full breeding and cytogenetic potentials of the crested wheatgrasses are to be realized, the nature and relative importance of pollination modes and reproductive mechanisms must be clearly defined. Additional information on

this problem was obtained at Logan, Utah, from a selfing experiment involving 122 diploid, 1,816 tetraploid and 40 hexaploid crested wheatgrass plants. The mean self-fertility of the diploid, tetraploid and hexaploid populations was 0.7, 2.7 and 9.6 seeds per spike, respectively, while the percentages of totally sterile plants were 72, 40 and 18 percent for the same three populations. Interannual variation in self-fertility was large. The 45 most self-fertile tetraploids averaged 37.4 self seeds per spike in 1961 as compared with an average of 15.8 in 1962. However, the relative self-fertility of the same 45 plants remained somewhat the same from year to year as shown by a highly significant correlation ($r=.78$). There did not appear to be any association between self-fertility and morphological characteristics. The association between cross and self-fertility was either non-existent or small as shown by correlation coefficients of $r=.14$, 122 and $.54$ for diploid, tetraploid and hexaploid populations, respectively. Results from this experiment suggest that selfing will be of limited value in breeding tetraploid crested wheatgrass, although selfing may be useful in genetic investigations. On the other hand, if most hexaploids prove to be as self-fertile as the sample studied, then selfing could be effective in the improvement of hexaploids.

8. Combining ability for seed yield and seed weight in crested wheatgrass. A series of 2-clone combinations tested at Mandan, North Dakota, averaged 657 pounds of seed per acre compared with 414 pounds for Nordan crested wheatgrass. However, seed weights of only three 2-clone combinations were significantly higher than Nordan. The heaviest-seeded combination, in which the reciprocal progenies averaged 341 and 336 milligrams/100 seed as compared with 287 milligrams for Nordan, involved the two heaviest-seeded clones. Seed yields of these two reciprocals were significantly lower than both members of the remaining 2-clone combinations. The first generation of one 2-clone combination exceeded Nordan by 66% in seed yield and 15% in seed weight. The importance of specific combining ability in conditioning seed yield and seed weight was indicated by the relatively poor polycross progeny performance of the two parental clones involved in this particular combination. Apparently the two parental clones complemented one another, as one was average in seed production and exceptionally heavy-seeded while the reverse was true for the second parent. It remains to be seen if clones selected on the basis of superior polycross progenies will lead to the production of outstanding 2-clone combinations.

9. New sorghum x sudangrass hybrid. A sorghum x sudangrass hybrid, developed at Lincoln, Nebraska, has been released for use in the Central Great Plains. The hybrid is a cross between male-sterile Martin and a low hydrocyanic acid sudangrass selection (N-7035). The hybrid, which has been tentatively named Nebraska Su-1, compares favorably with Piper and Wheeler sudangrass in forage yield both as pasture and

green chop. Stem-size and leaf width are larger than the two sudan-grasses but less than some sorghum x sudangrass hybrids. It has good seedling vigor and rapid recovery after each harvest. The hydrocyanic acid potential is low enough for grazing purposes (143 ppm. compared with 89 ppm. for Wheeler and 50 ppm. for Piper sudangrass). Because of the possibility of lodging it should not be grown for either mature forage or silage. Seed of male-sterile Martin and the pollinator, N-7035, will be distributed for certified seed production in 1963.

10. Influence of environment on asexual reproduction. The effect of environment on apomictic reproduction is being investigated at Tifton, Georgia. Apomictic and sexual plants isolated from the cross between a sexual, colchicine-induced tetraploid of Pensacola bahiagrass and a selection of apomictic common bahiagrass were used in these tests. Ten clones were increased vegetatively and planted at Blairsville in North Georgia and at Tifton. The ten clonal lines included four obligate apomicts, three sexuals with no apomictic segregates and three sexuals segregating for apomicts (as classified from seed produced at Tifton). Seed was harvested from each clone at these two locations several times during the year, with the last harvest being made after frost. Large space-planted populations from these seed lots indicated that 3 of the 4 clones, originally classified as obligate apomicts, were obligate apomicts at both Tifton and Blairsville. The fourth clone was apomictic at Blairsville but apparently sexual at Tifton. The three clones classified as sexual were sexual at both locations. Two of the three clones that had been previously classed as sexual but with large numbers of apomictic seedlings proved to be sexual at both places. The third clone in this category gave completely apomictic progenies in seed harvested at Blairsville and Tifton. In 1962 additional seed was collected at both locations in order to continue the study of environmental effects on apomictic reproduction.

11. Improved growth-habit through irradiation. Yellow-anthered dallisgrass, a highly fertile introduction from Uruguay, has been of little value because of poor leafiness and an extremely upright growth habit. However, radiation of dormant seed of this sexual ecotype has led to the development of promising decumbent lines at College Station, Texas. Vigorous decumbent mutants were recovered in the first mutagenic (M_1) generation but extreme segregation for growth habit was encountered in succeeding generations. With rigid selection for decumbent type, satisfactory uniformity has been achieved in some M_5 lines. In 1962 five M_5 lines contained 72 to 100 percent decumbent plants. The better lines also show improved vigor, leafiness and good fertility. The forage characteristics of the best M_5 lines will be compared with commercial varieties in 1963. Radiation has also been used at College Station, Texas, to change the growth habit of vaseygrass. Progress with this species has been slower and the results less promising than with yellow-anthered dallisgrass.

12. Amphidiploids of annual ryegrass-tall fescue. Colchicine has been used at Lexington, Kentucky, to produce partially fertile amphidiploids ($2n=56$) from highly sterile F_1 hybrids ($2n=28$) of annual ryegrass and tall fescue. The relatively small number of amphidiploids produced in this manner has limited the opportunity to select for improved fertility. However, a new technique for isolating large numbers of amphidiploids has been developed through cooperative studies at Lexington, Kentucky, and University Park, Pennsylvania. Seed was obtained by pollinating highly sterile F_1 hybrids with colchicine-induced amphidiploids. Most of the plants grown from this seed had 56 chromosomes, and apparently originated through the fertilization of unreduced egg cells in the F_1 ($2n=28$) with reduced pollen grains ($n=28$) from the amphidiploid pollinator. The substantial number of amphidiploids produced from these crosses will facilitate selection for improved seed set, testing the stability of amphidiploids and evaluation of experimental 56-chromosome varieties.

13. Progress in hybridizing Old and New World wheatgrasses. Interspecific and intergeneric hybrids are valuable in establishing phylogenetic relationships among species, and may contribute either directly or indirectly to the development of promising grass varieties. A North American wheatgrass species, Agropyron spicatum, was crossed with an Old World species, A. cristatum, at Logan, Utah. The cross A. spicatum ($2n=28$) x A. cristatum ($2n=14$) produced a triploid hybrid ($2n=21$). Chromosome pairing in the hybrid usually resulted in the formation of 7 bivalents and 7 univalents. Size differences between the chromosomes of the two parental species made it possible to identify the 7 bivalents as resulting from autosyndesis of 14 A. spicatum chromosomes, whereas the 7 A. cristatum chromosomes were left as univalents. These data suggest that A. spicatum is an autopolyploid, and that none of its chromosomes are homologous with those of A. cristatum.

14. Collections of indigenous grasses in Rio Grande do Sul, Brazil, under the term of a PL 480 contract. Information was obtained on the forage value and adaptability of some 357 grass species, and collections established in adaptation trials at 9 locations in the State. Extensive nurseries of 12 major species were established for detailed studies on breeding behavior and cytogenetics.

B. Diseases.

1. Foreign smut disease attacks pearl millet. In 1962, Tolyposporium smut of pearl millet caused by T. penicillariae was found for the first time in the United States at Tifton, Georgia. The smut is the most serious disease of millet in India and Africa where the grain is used for human food. In the United States millet is used principally for forage. No satisfactory control measures have been developed in countries where the disease is severe. Precautions such as seed treatment with fungicides and rigid inspection are under way to prevent spread of the disease to western seed-producing states. All millet nurseries

at Tifton are being burned and treated with fungicides to eradicate the smut if possible.

2. Fungicide treatment controls turf fairy ring. At Tifton, Georgia, the pesticides Captan 50-W, Phygon X6, Terraclor, dieldrin, and Nema-gon were separately rototilled into plots of centipedegrass affected by the fairy ring fungus. The treated areas were reseeded after treatment. Plots receiving 5 and 10 pounds per acre of Captan 50-W became completely covered with grass regrowth. Plots treated with Phygon XL at 2 lbs/acre were rated next best. Poor grass regrowth occurred in the untreated control and in the other pesticide-treated plots.

3. Fungicide phytotoxicity to turfgrasses related to drought and temperature. Centipedegrass, zoysia and bermudagrass varieties were not injured by spraying at weekly intervals with PMAS at up to 3 oz. and Panogen at up to 6 oz/1000 sq.ft. Only slight phytotoxicity was observed at 6 and 12 oz. rates, respectively, of the above fungicides. St. Augustinegrass was severely discolored when 1-1/2 oz. of PMAS and 3 oz. of Panogen/1000 sq.ft. were applied. Tests in temperature, controlled chambers demonstrated that PMAS and Panogen were both more phytotoxic to bentgrasses at 90°F. than at 70°F. Grass blades dehydrated before spraying with fungicides were injured at both temperatures.

C. Variety evaluation.

1. Bermudagrass varieties differ in wear tolerance. The wear tolerance of improved bermudagrass varieties has been tested at Tifton, Georgia, by driving golf carts over well-established turf. The experiment was designed to evaluate varieties, various management treatments and the effect of tire design on golf carts. In this test Tiflawn was the most resistant to wear, followed by Tifway. The poorest wear tolerance ratings were assigned to Tifgreen and common. Golf carts equipped with wide smooth tires inflicted less damage than those equipped with narrow tires. Watering during dry weather, fertilization and raising the height of cut increased wear tolerance of the varieties tested. The increase in wear tolerance that was obtained from these treatments may be attributed in part to an increase in amount of growth or density. As the volume or rate of growth increased, varieties could withstand more wear before bare ground appeared.

2. Shade tolerance of bentgrass. Information was obtained at Beltsville, Maryland, on the relative shade tolerance of bentgrass varieties that are widely used for putting greens. Two replications of a bentgrass variety trial were covered for two months, in each of two years, with screens that excluded 30 percent of the light intensity. Significant differences were noted among varieties in their response to shade and sunlight. The Washington variety was rated best for both shade and sun under the conditions of this experiment. Most varieties

performed better in full sunlight than in the shade, but Pennlu produced somewhat better turf under shade than in the sun. In general, varieties that performed best in sunlight were also better under shade. Since all varieties received the same management treatments, these results may differ considerably from a test in which each variety was managed according to its individual requirements.

D. Cultural investigations.

1. Black grama responds to good management. Black grama is noted for its erratic and generally low seed set under range conditions. This fact has suggested the possibility of selecting for improved seed set and higher seed yields as an aid to using this valuable species for range reseeding. However, studies at Tucson, Arizona, have shown that black grama will produce reasonably good yields under cultivation. Initiating growth by irrigating on August 1 was superior to irrigation schedules starting on August 15, both from the standpoint of seed yield and percent germination of the harvested seed. Applications of nitrogen increased seed yields in some tests but not in others, while phosphorus and potassium had no appreciable effect on seed-set, seed yield, seed weight or germination percent. The seed yield of black grama could be improved by selection, but in the meantime there are no real barriers to increasing seed under irrigation for use in reseeding projects. Lack of seed-set on the range may be attributed to indeterminate flowering under natural rainfall conditions, and lack of pollination among widely separated plants.

Of about 100 native and exotic economic grasses, about 25 are included in active research programs and some 45 legumes are the subject of state, regional, or national research. Many introductions serve as sources of germ plasm containing desirable agronomic characteristics worthy of transfer to field crop varieties.

Orchardgrass introductions which serve as examples of valuable germ plasm include: P.I. 220877 (Ireland), 230116-117 (Iran), 231551 (Italy), 235474 (Switzerland), and 237265 (Denmark). The accessions of Cynodon dactylon, P.I. 206657 (Turkey), 211021 (Afghanistan), 213384 (S. Africa), 213385 (S. Africa), 213387 (S. Africa), 213389 (S. Africa), 222789 (Iran), and 224691 (S. Africa) show promise of direct usage as pasture grasses or in breeding programs in Arizona and California. Accessions of Echinochloa, PI. 18332 (India), 196291 (India), and 223254 (Afghanistan), are reported as being good sources of wildlife food. Germ plasm containing earliness in corn is represented by P.I. 228173 (USSR) and that containing the tillering character is found in P.I. 167959 (Turkey). Two Digitaria accessions, P.I. 279651-652 (Taiwan), were introduced specifically in the search for disease resistance, virus stunting disease, and cold tolerance. A bermudagrass, P.I. 224693 (S. Africa), has entered commercial channels in Texas and is in widespread usage throughout

the south-central portion of the state. Exceptional cold hardiness is exhibited by one introduction of blue panicgrass, P.I. 268410 (Afghanistan). This introduction survived the 1961-62 winter at Ames, Iowa, with very little winter injury.

The following varieties of pasture grasses with plant introduction parentages were released during the interim of this report: A new synthetic variety of brome grass, 'Sac', has good resistance to seedling and foliage diseases. The variety was released jointly by the University of Wisconsin and the USDA; it has good vigor and seed producing ability. 'Oahe' wheatgrass, released in South Dakota, is vigorous, early maturing and a good seed producer. A new orchardgrass 'Sterling', an Iowa release, rates high in winter hardiness and in ability to produce excellent stands.

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PASTURE AND RANGE SEEDING, ESTABLISHMENT,
MANAGEMENT AND EVALUATION
Crops Research Division, ARS

Problem. Grazing lands of the United States occupy approximately 1,000 million acres as compared to 350 million acres of all harvested crops. It has been estimated that more than half of all the nutrients consumed by domestic livestock are provided by pastures and ranges. Improved grasslands are also essential to soil and water conservation and to provide cover in the preservation of our greatest natural resource, the land. Because of the diversity of problems and conditions, research on lands used for grazing must cover wide ranges of interests and investigations. Grazing lands represent a highly diverse part of the land resource, and because of this diversity, present a tremendous challenge to research. Information must be obtained on reliable, practical procedures for grassland management and to determine the response of the many species involved to different grazing practices. Pasturage must also be palatable and meet the nutritional requirements of the grazing animal as far as possible. The production pattern must be organized in such a manner that uncertainty of yields is reduced to a minimum. More precise information is needed as to what plants or mixtures meet the requirements for yield, quality, resistance to heat, drought, and other hazards. Considering the importance of our grassland agriculture, pasture and range crops must be investigated during all stages of growth and at all grazing seasons. Some of the major areas of research needing attention are concerned with seeding and establishment, including basic and applied physiological studies on the responses of pasture and range species and mixtures for different environments and management practices; the relationship of grazing use to the vigor and persistency of pasture and range species, including basic studies on root reserves, biochemical constituents, and the initiation and development of primordia of reproductive and vegetative culms; and the more effective integration of the total feed resource into a program yielding maximum animal products concurrent with a buildup of the pasture and range resource.

PROGRAM

The Department has a continuing long-term program involving agronomists, plant physiologists, range conservationists and chemists engaged in basic and applied research on the management and improvement of grazing lands, native meadows and improved pastures. All work is cooperative with the respective states and with the U. S. Forest Service in areas where grazing is integrated with National Forests. Research in seeding and establishment, management, and

varietal evaluation is in progress at Berkeley, California; Ft. Collins, Colorado; Beltsville, Md.; Bozeman, Montana; Reno, Nevada; Las Cruces, New Mexico; Woodward, Oklahoma; Burns, Oregon; Beaumont, Texas; and Logan, Utah. Research in management and varietal evaluation is in progress at Gainesville, Fla.; Tifton, Ga.; St. Paul, Minnesota; Columbia, Mo.; Miles City, Mont.; Ithaca, N. Y.; Raleigh, N. C.; Mandan, N. Dak.; University Park, Pa.; and Pullman, Washington. Seeding and establishment, and varietal evaluation is in progress at Mesa, Arizona. Processing research is in progress at Tifton, Ga., and Beaumont, Texas; seeding research at Twin Falls, Idaho; and varietal evaluation research at Lafayette, Indiana. Research at Bozeman, Mont., and Mandan, N. Dak., is conducted cooperatively with Soil and Water Conservation Research Division and at Miles City, Montana, with Animal Husbandry Research Division. At Twin Falls, Idaho, and Burns, Oregon, Bureau of Land Management is a cooperator and at Logan, Utah, Bureau of Indian Affairs of the U. S. Department of Interior.

The federal scientific effort devoted to research in this area totals 35.7 professional man-years. Of this number 5.5 is devoted to seeding and establishment, 0.3 to processing, 17.2 to management, 11.2 to varietal evaluation, and 1.5 to program leadership.

A PL-480 contract has been negotiated with the Hebrew University, Jerusalem, Israel, under which they will investigate the Developmental Physiology of Perennial Pasture Grasses. This is project A 10-CR-27, (1961-1965).

A PL-480 contract has been negotiated with the Agricultural Experiment Station, the National and University Institute of Agriculture, Rehovot, Israel, under which they will investigate Establishment and Maintenance of Seeded Dryland Range Under Semiarid Conditions. This is project A 10-CR-45 (1963-1966).

PROGRESS

A. Seeding and Establishment

1. Cool Temperatures Deleterious to Subtropical Grasses. In many subtropical regions marked seasonal variations in forage production are observed, although temperatures are well above frost and climatic conditions seem favorable for the rapid growth. In order to delineate the effect of cool day or night temperatures on the growth and development of subtropical forage plants, an experiment was conducted at Beltsville, Md., in controlled environment growth rooms at 50, 70, and 90°F. For Pangolagrass growth was maximized under a constant 90° temperature. Reduction

of night temperature to 70° resulted in a 25% decrease in dry weight. Decreasing the night temperature to 50° resulted in an additional 26% decrease in dry weight. Stolon numbers and stolon lengths were similarly decreased under the lower night temperature. Coastal bermudagrass responded similarly to low temperatures. Pearl millet, one of the annual subtropical forage grasses, also gave highest yields in seedling stages with the higher night temperatures and sharp reductions occurred with lower night temperatures. With pearl millet a striking reduction in growth occurred with the 50° night temperature. The yield for this treatment was only 1% of that for the 90° continuous temperature and no tillering was evidenced at the lower temperature. Severe chlorosis occurred in the pearl millet subjected to 50° and this, no doubt, accounted for the marked reduction in photosynthetic activity. Since the mean temperatures in August, September, and October in the southern United States, are comparable to the lower temperatures in these experiments, it is likely that the drop in night temperatures is the primary cause for reduced late summer and fall growth of the subtropical grasses. Similarly, a failure of many of the subtropical grasses to give expected establishment and production in the tropics at the higher elevations should be anticipated.

2. Shade Improves Seedling Environment on Southwestern Rangelands. Near Las Cruces, New Mexico, on the Jornada Experimental Range, high soil temperatures and associated periods of moisture deficiency can be considerably moderated by the shade provided by brush killed by the rootplow. A tarbush site was rootplowed and seeded June 25. During the period July 2 to September 20 areas not shaded by plowed-out tarbush provided 1, 6, and 16 days with soil moisture above wilting at the 1/2, 2, and 4-inch depths, respectively. During the same period and comparable depths on areas shaded by plowed-out tarbush, there were 25, 55, and 67 days, respectively, above wilting. At the 1/2-inch depth soil temperatures in the open reached 131°F while 106°F was the highest temperature recorded in shaded areas, temperatures ranging from 14 to 29° lower. On a creosotebush site a comparable study gave 9, 32, and 36 days with moisture above wilting at the 1/2, 2, and 4-inch depth on exposed soil, and 29, 40, and 64 days where plowed-out creosote bush shaded the soil. At the 1/2-inch depth maximum temperature recorded was 138° on exposed sites, and on shaded sites 18 to 37° cooler. Furrows and pits aided in preserving moisture but were less effective in reducing soil temperature. Seedlings in furrow or pit bottoms were also buried by loose sand. The studies suggest that seeding under the shade of plowed-out brush may be successful on rangelands not previously revegetated by other methods.

3. Chemical Fallow and Furrows Effective in Cheatgrass Replacement.

The intense competition which cheatgrass provides seedlings of desirable forage species can be virtually eliminated by herbicides according to studies cooperative with the Crops Protection Research Branch at Reno, Nevada. Paraquat at .7 lbs/acre in combination with a surfactant, X-77 at .1% reduced cheatgrass from 25.8 plants/sq. ft. to less than 1, and cheatgrass yields from 633 lbs/acre to 12.6 pounds. Less expensive, but somewhat less effective control of cheatgrass was provided by Atrazine, IPC and isocil, which reduced cheat to 3.2 plants/sq.ft. Perennial grasses seeded in furrows on chemically fallowed land yielded 1.8 seedlings/foot of row as compared with .9 seedling/foot on surface drilling. A 2-year old grass stand seeded on a chemical fallow yielded 824 pounds grass/acre from furrow seeding compared with 530 pounds from surface drilling. A 1-year old grass stand on chemical fallow gave the following yields and plants per foot row: 1,088 pounds and 1.6 plants for intermediate wheatgrass; 519 pounds and 1.5 plants for pubescent wheatgrass, and 364 pounds and 1.0 plant for crested wheatgrass

4. Podosporiella Verticillata Widely Distributed in Range Soils.

At Logan, Utah, and Beltsville, Maryland, studies have shown that the fungus P. verticillata could be a major factor in the failure of many range seedings. It is widely distributed in the sagebrush type in the Western States, having been identified on seeds from control studies in Utah, Nevada, Idaho, and Montana. It has also been found in the shadscale and mountain brush types. Early studies suggest that infection from the soil-borne fungus is most likely on fall planted seeds, when they have absorbed some moisture, but where moisture and temperature are not adequate to initiate rapid germination and growth. Seed treatment with Captan 75 gives good control.

B. Processing

B₁ Silage

1. Low Cost Silage Structures for the Gulf Coast. At Beaumont, Texas, in cooperation with agricultural engineers, low cost methods of storing silage are being studied in a search for effective ways to preserve surplus spring and early summer ryegrass-clover forage for winter use. Bunker and stack silos with self-feeding gates have cut labor costs and produced good silage both from wilted and unwilted forage. Wilted silage was shown to have two advantages: (1) reduced moisture content with less weight to transport and store, and (2) added vitamin D resulting from the extra sunlight during the wilting process. Since the most important requirement for the successful storage of silage is exclusion of air, better silage was produced with the tighter packing shorter cuts (3/8 inch).

In the Gulf Coast region sealed bunker silos saved more feed and produced better silage than unsealed bunker and stack silos. Cattle showed a marked preference for silage that had been adequately sealed and animal performance was better on the higher quality silage.

B₂ Pelleting

1. Coastal Bermudagrass Pellets Give Best Animal Gains. At Tifton, Ga., a utilization study of Coastal bermudagrass in cooperation with Animal Husbandry and Agricultural Engineering Divisions was established to compare continuous grazing, rotational grazing, strip grazing, green chop, dehydrated hay, and pellets. Pellets gave the best animal performance and highest production per acre. The average pounds daily gain for the treatments was as follows: Continuous grazing 1.3; rotational grazing 1.2; strip grazing .7; green chop .6; hay 1.1; and pellets 1.5. Animal production per acre likewise was highest from the hay and pellet treatments.

C. Management

C₁ Grazing

1. Selective Grazing Not Related to Fertility Imbalance. Selective grazing on rotation pastures was mapped in 1961 and 1962 at St. Paul, Minnesota, and data showed that 80 percent of the dung spots deposited one month previously produced forage islands that were not consumed at the next grazing. Following a delay of two or three months 66 percent of the dung-caused forage islands were still completely rejected. The effect of the dung spots on grazing patterns was almost completely eliminated by overwintering of the sward. Urea, at 900 pounds of N per acre, did not cause a rejection of forage grazed. Heavy concentrations of phosphorus applied to the dung did not overcome forage rejection. The application of phosphorus and high concentrations, about 2,000 pounds per acre to brome grass did not increase acceptability of forage growing near dung spots when measurements were made one to three months following deposition of dung and phosphorus. Formation of simulated dung spots by heavy applications of nitrogen on nitrogen deficient brome did not decrease acceptability of the dense dark green tussocks which resulted, since 98 percent of these simulated dung spots were completely consumed. The results oppose a thesis that rejection by cattle of forage grown near dung spots is a result of nutrient imbalance within a plant caused by excess nitrogen and low phosphorus.

2. Bluegrass-Ladino Pastures Highest Yielding. At Columbia, Missouri, Kentucky bluegrass-ladino clover and orchardgrass-ladino clover pastures have been evaluated for 6 years, under a 3-paddock rotation management system. The bluegrass-ladino pastures have given superior animal performance with average daily gains of 1.71 pounds and total beef gains of 237 pounds per acre compared to average daily gains of 1.34 and total beef gains of 1.98 for the orchardgrass-ladino pastures. During the dry season of 1962, however, the orchardgrass outyielded the bluegrass pastures both in daily gains and total animal production.

3. High Quality Pasture Not Improved by Concentrate Feeding. At St. Paul, Minnesota, in cooperation with the Dairy Husbandry Department, a supplemental feed test involved two sets of identical twin Holstein cows on an excellent quality alfalfa-brome pasture from June to September. One twin of each set received 16 pounds of high energy concentrate per day while the other received none. In set one the concentrate-fed twin produced 25.2 pounds of milk per day while the one on alfalfa-brome pasture without concentrate produced 26.1 pounds. In the second set the average daily milk yields were 49.4 and 38.3 pounds of milk per day by the concentrate-fed and nonsupplemented cows, respectively. The increase in milk production by the grain-fed cow of the second set did not pay for the cost of the concentrate.

4. Sixweeks Fescue Completely Controlled with Simazine. At the Central Plains Experimental Range near Fort Collins, Colorado, sixweeks fescue (*Festuca octoflora*) an undesirable component of the range vegetation can be completely controlled by an application of 3-1/2 lbs/acre of simazine applied in early October following seasons favorable for fescue development. Forty lbs. N/acre slightly increased fescue frequency. On plots without treatment, given 40 lbs. N/acre, or 3-1/2 lbs. simazine/acre, sixweeks fescue and blue grama yields, respectively, were 90 and 469 lbs/acre, 220 and 552 lbs/acre, and zero and 618 lbs/acre, respectively. N fertilization increased utilization of blue grama by livestock on fescue-infested range, but also greatly increased fescue. Residual effects will be noted in 1963.

5. Russian Wildrye Highly Productive on Northern Plains Rangeland. At Mandan, North Dakota, in the favorable 1962 field season Russian wildrye produced the highest per acre gains recorded in 47 years of grazing management studies. A solid drilled pasture receiving 40 pounds N/acre, grazed for 75 days with yearling steers, yielded 248 lbs. beef/acre. Comparable crested wheatgrass pasture was grazed for 55 days and yielded 208 lbs. beef/acre. Nonfertilized native range, grazed for 140 days, yielded 58 pounds beef/acre. The three pastures provided 127, 100, and 31 steer days

grazing/acre, respectively. Gains per head were better maintained throughout the grazing period on Russian wildrye and native range than on crested wheatgrass, but in early spring there were no differences. Russian wildrye maintained a high level of protein throughout the season, ranging from 22.8% on May 22 to approximately 8% in late fall when native range was between 3 and 4%.

6. Alfalfa Enhances Production of Crested Wheatgrass on Rangeland.

At Mandan, North Dakota, a 7-year study indicates significant advantage of a crested wheatgrass plus alfalfa mixture over crested wheatgrass alone. Alfalfa remained in the mixture and caused no bloat problems, in the seventh season constituting 33% of the forage. Average gains pounds per head were 89.7 and 101.5 for crested wheatgrass and the mixture, respectively. Gains per acre were 104.6 and 133.5, respectively; pounds dry matter per acre produced at hay stage 1,773 and 2,403, respectively; and TDN per acre 402.1 and 492.8, respectively. Only in the very dry 1959 season was the mixture less productive than crested wheatgrass, the advantage of the mixture being enhanced in favorable seasons. Crested wheatgrass fertilized with 40 pounds N/acre each year, exceeded the mixture in yield. The average value of beef per acre was \$27.13, \$40.48, and \$48.45 for crested wheatgrass, the crested plus alfalfa mixture, and crested plus 40 pounds N/acre, annually, respectively.

7. Santa Gertrudis Compare Favorably with Herefords on Jornada.

At Las Cruces, New Mexico, the grazing habits of the two breeds are very similar but Santa Gertrudis produce weaners more efficiently. Hereford steer calves weaned at 254 days averaged 457 pounds while comparable Santa Gertrudis at 224 days averaged 502 pounds. Hereford heifer calves at 246 days averaged 469 pounds while comparable Santa Gertrudis at 206 days averaged 468 pounds. Both breeds reached maximum weights in December and January. Herefords lost 22% of their weights to reach the lowest level in May while Santa Gertrudis lost 26% by early July. A striking difference between the two breeds was reflected in milk production, comparable in May and July but on August 28 Hereford cows averaged 3.4 pounds and Santa Gertrudis 10.7 pounds. This may explain the larger calves weaned.

8. Infiltration Rate Strikingly Reduced on Grazed Range. At Woodward, Oklahoma, compaction of range soils, even by light grazing, very markedly reduced infiltration rate as determined by sprinkler infiltrometer studies conducted cooperatively with SWC. Rangeland stocked yearly at 12, 17, and 22 acres per head yearlong, and non-grazed range gave infiltration rates of 2.2, 3.6, 4.3, and 10.6 inches per hour, respectively. The corresponding soil bulk density

values were 1.65, 1.61, 1.60 and 1.52, respectively. The study was conducted on Pratt loamy fine sand. If similar relationships are found on soils whose infiltration rate is lower, where runoff occurs following every effective rain, the development of grazing systems that interfere least with infiltration will become a major objective of the program.

9. Irrigated Russian Wildrye Develops Extensive Root System. At Mandan, North Dakota, Russian wildrye in rows 36 inches apart produced 13,435 pounds of roots in the top 8 feet of soil, of which nearly 60% were in the top foot. Seventy-six percent of all roots were in the half of the soil profile directly under the rows. When rows were spaced only 9 inches apart 10,490 pounds roots were produced, uniformly distributed at any horizontal level. During 4 years of the study, forage yields increased with each additional increment of N fertilization up to 400 lbs/acre. Root yields reached maximum productivity at 200 pounds N/acre. Nitrogen fertilization contributed most to root yield in the top foot of soil.

C₂ Basic Physiology

1. Prefreeze Management and Winterkilling of Oats. At Gainesville, Fla., studies on Florad oats show the height of clipping, age, and regrowth significantly affected a number of plants killed by freezing treatment. Killing was greater in the 2- than either the 4-, 6-, or 8-inch stubble height. These results indicate that grazing to a shorter stubble would increase low temperature killing. In general older plants in all heights of cuts and regrowth treatments were more susceptible than young plants to low temperatures. However, a significant interaction occurred since the 6 week-old plants were markedly more freeze resistant than either younger or older plants. These findings suggest that little or no damage from freezing will occur in 6- and 7-week-old plants of Florad variety oats even if grazed to a 2-inch stubble height; however, because of the increase in susceptibility of older plants to freezing, oats should be grazed before they reach 9 weeks of age.

2. Short Daylengths Stimulate Adventitious Rooting of Alfalfa. At University Park, Pa., creeping-rooted alfalfa was found to produce twice the number of adventitious stem sites during two months' growth under shortening daylengths (14.7 hours decreasing to 11.7 hours) than during a similar period under longer daylengths (15.7 hours in early summer). Gibberellic acid has been shown to negate the effect of short days on stem elongation.

3. Temperature and Solar Radiation Influence Ryegrass. At Beaumont, Texas, a study on growth of Gulf ryegrass as influenced by temperature and solar radiation showed that temperature had more effect on winter growth than did solar radiation. Based on a computed regression equation, a formula has been developed for estimating production of ryegrass and calculations show that relative growth rates of 100% would be obtained from ryegrass, even in the coldest recorded Aprils or Octobers. During November or March, for the coldest months normally experienced, production would be only 50%. For those coldest Decembers and Februarys relative production is computed at 25%, and for the coldest Januarys, production would be zero. For an average temperature experienced in January, on the other hand, ryegrass growth would be 70%.

4. Light Utilization of Bermudagrass. Light frequently sets the ceiling on yields of forage plants. At Beltsville, Maryland, the relation of amount of leafage and rate of net photosynthesis was studied in a climate controlled laboratory. These studies show that at least 300 foot-candles of light is required to reach the compensation point, i.e., where photosynthesis balances respiration. The amount of leafage markedly affected the photosynthetic rate, and leaf quantities either too low or too high reduced the growth rate. This work suggests that an optimum quantity of leafage exists which will maximize growth rate. Thus efficiency of light utilization is a manipulative factor in grazing or cutting management.

5. Fertility Needs of Ryegrass Determined by Leaf Analyses. At Berkeley, California, laboratory studies with Italian ryegrass have shown that nitrate accumulation in young leaves may be a reliable indicator of the nitrogen fertility status of the plant. Plants were grown in nutrient solutions with only nitrogen limited or variable, and six plant parts analyzed for NO_3 accumulation. On the basis of dry weight yield responses, under the conditions of this study the critical level of N fertilization is indicated by an NO_3 concentration of 1,000 ppm in the youngest fully open leaf. A lower concentration in this leaf indicates that the plant will respond to additional N fertilization. The method will be tested under field conditions and if effective will be extended to other nutrients and species. The study was conducted in cooperation with the Department of Soils of the University of California.

6. Moisture Stress Distorts Metabolic Processes in Subterranean Clover. Studies at Pullman, Wash., have shown that not only metabolic processes, but the phosphorylated intermediates upon which they are entirely dependent, are affected by moisture stress. Concentrations of ribulose diphosphate, phosphoglyceric acid, glucose-6-phosphate, uridine diphosphate glucose, and other phosphorylated intermediates

were markedly decreased in plants whose relative turgidity was reduced to between 50 and 75%, and were decreased to less than half that of control plants when severe wilting was permitted. Inorganic phosphate was not affected. Marked recovery in most phosphorylated intermediates occurred within 24 hours after severely wilted plants were irrigated. These studies help to explain the physiological effects of moisture stress in plants and suggest a need for studies on the effect of moisture stress on phosphorylating processes and the synthesis and breakdown of enzymes which catalyze the interconversion of these intermediates.

7. Alfalfa and Birdsfoot Trefoil Respond Differently to Soil Temperature. Ranger alfalfa, 15 weeks after planting, consistently yielded more root growth than Tana birdsfoot trefoil in studies at Bozeman, Montana, but herbage growth relationships depended on soil temperature. In a 16-hour photoperiod, with air temperature at 21°C, the yield of alfalfa roots exceeded those of trefoil by 80, 90, and 130% when soil temperatures were 12, 18, and 24°C, respectively. Under the same conditions alfalfa herbage growth was 80% more, and 10 and 23% less, respectively. The ratio of root growth to herbage growth in alfalfa remained fairly constant at the three soil temperatures, averaging 1.15:1. Birdsfoot trefoil root to herbage ratio decreased from 1.27:1 at 12°C to .39:1 at 24°C. Phosphorus fertilization at three levels did not bring out significant differences between the species, but was most beneficial at the lowest soil temperature. Birdsfoot trefoil required 49, 75.8, and 78.2 square centimeters of leaf surface (1 side only) to produce 1 gram dry matter (forage plus roots) at 12, 18, and 24°C, respectively, while alfalfa needed only 38.2, 49.7, and 48.1, respectively.

8. Developmental Physiology Studies Progressing in Israel. In the work reported to date two phases of the problem have been initiated; (1) a study of summer dormancy in Hordeum bulbosum, an important drought resistant range grass, and (2) the development of equipment for the simultaneous and continuous determination of net photosynthesis and transpiration of intact plants. Detailed results have not yet been reported from either of these studies.

D. Variety Evaluation.

D₁ Variety Comparisons

1. Alfalfa Management. Dupuits and Naragansett alfalfa were studied at Ithaca, New York, over a 3-year period in an experiment involving frequency and intensity of defoliation and levels of P and K fertilization. Frequency of cutting has been the largest

single factor affecting yield, with two cuts per year giving highest production. In this study a unique harvesting technique to simulate gradual removal of herbage by grazing animals showed that taking in the harvest in two parts separated by 10 days gave slightly increased yields, particularly with more frequent cutting treatments. As expected, higher yields were also produced with increased phosphorus and potassium fertilization. Root weights were higher for the plants clipped leaving a 6-inch stubble compared to those cut to 2 inches.

2. Vernal and Ranger Alfalfa Superior to Rambler and Teuton. The superiority of Ranger and Vernal alfalfa over the low growing varieties, Rambler and Teuton, was confirmed at St. Paul, Minnesota, under both clipping and grazing by sheep. When the botanical dominance in the legume grass mixture was used as a criterion, plant counts revealed that nitrogen fertilization resulted in a decrease in legume stands and production, as contrasted to earlier results on a very fertile soil where nitrogen fertilization did not affect alfalfa stands.

3. Factors Affecting Nitrate Accumulation in Forages. In controlled environmental studies at Ithaca, New York, several affected the accumulation of nitrate in plants. These factors are now being studied to determine their effect on the nitrate reductase enzyme, and to assess the importance of this enzyme in nitrate accumulation. Both the level of nitrogen in the growth medium and the air temperature have pronounced effects on nitrate reductase activity of plant extract. Enzyme activity increases with an increase in nitrogen and decreases with an increase in temperature.

4. Grass Variety Comparisons. At Columbia, Missouri, in a 4-year study Sterling was the highest yielding of the 12 orchardgrass varieties tested and outyielded either Potomac or Common. In a fescue variety comparison, yields of Oregon 4-36, Kentucky 59-G1-32, Ky. 31, Alta, and Goar have been essentially the same. In a Reed canarygrass test Ottawa 1133-7 was the highest yielding of the eight varieties tested.

5. Sagebrush Continues to Invade Native Range. At Burns, Oregon, over the past 9 years, sagebrush continues to invade poor and fair condition range. On poor condition range sage increased under all levels of N fertilization, most rapidly at N levels up to 60 lbs/acre and in favorable seasons. Grasses adversely affected by N fertilization included bluebunch wheatgrass, June grass and Thurbers needlegrass. In striking contrast squirreltail increased 12-fold with N fertilization. On fair condition range perennial grasses declined from 90% to 30% of the total herbage, being replaced by cheatgrass and weeds. The change was accelerated by N

fertilization. On good condition (seeded) range sage declined slightly during the 9-year period.

6. Cheatgrass Aggressive on Fertilized Range. At Pullman, Wash., cheatgrass increased and Agropyron spicatum decreased on fertilized range and the reduction in A. spicatum was accelerated by clipping at ground level during any stage of growth. On poor-condition range other grasses (primarily cheat) yielded 1/2 ton/acre on control plots and 2 tons/acre following 2 years of fertilization with 80 lbs. N/acre. Comparable figures on good-condition range were 1/4 ton and 1-1/4 tons, respectively. When mature A. spicatum was clipped at 8" the average ground cover was 7.9%. All plots clipped at ground level ranged between 3.7 and 4.8% ground cover.

7. Rapid, Objective, Method Developed for Noting Vegetation Changes. At the Central Plains Experimental Range near Fort Collins, Colorado, vegetation on blue grama range can be rapidly and objectively characterized by noting presence or absence of blue grama plants in a 2 by 2-inch quadrat and all other species in a 16 by 16-inch quadrat, of which the 2 by 2 is a part. Twenty-five quadrats on each of 10 transects were found to accurately and efficiently sample a 200 by 200-foot macroplot.

8. Western Wheatgrass and Blue Grama Opposites on Northern Plains Rangeland. When exposed to N fertilization and one to three harvests, western wheatgrass and blue grama are direct opposites in studies at Mandan, North Dakota. Plots harvested June 1, July 1, and August 1 over a 5-year period, without nitrogen fertilization, resulted in a 50% increase in blue grama and a 13% decrease in western wheatgrass. A single harvest August 1, with 160 pounds N/acre/annually resulted in a 54% decrease in blue grama and a 994% increase in western wheatgrass. The differential response was much greater in seasons of above normal precipitation than in dry years. A single harvest August 1 each year consistently gave higher yields than from harvests June 1 and August 1, or from harvests June 1, July 1, and August 1. Two annual harvests resulted in western wheatgrass population resembling those of plots harvested once only, while blue grama populations were more like those on plots harvested three times.

D₂ Chemical Composition and Nutritive Value.

1. Forage Quality Determined by Test-Tube Technique. At Lafayette, Indiana, the in vitro digestibility technique continues to give valid prediction of animal digestibilities. A correlation coefficient of .92 was obtained between in vivo digestible dry matter at the ad libitum level of intake and the in vitro digestible cellulose after an 18-hour period of fermentation. In a

palatability test Reed canarygrass clones were selected for a range of animal acceptability. Differences in palatability were confirmed in a conventional digestion trial. The ad libitum dry matter intake (pounds per hundred pound body weight) for the initial growth forage was 3.0, 2.9, and 2.6 for alfalfa; and the palatable and unpalatable groups, respectively. The nutritive value index results followed a similar pattern; 56, 56, and 49.

2. Digestibility of Plant Parts. At Tifton, Georgia, four inbred lines and one pearl millet hybrid, harvested at three stages of maturity, were separated into leaf blades, leaf sheafs, stems, and heads, and all parts were analyzed chemically and subjected to an in vivo digestion. Dry matter (digestibility) averaged 69.6, 55.9, and 51.0, at grazing, root, boot, and dough stages. In the grazing stage stems were more digestible than leaves, while at later stages of maturity the reverse was true.

3. Chemical Tests for Digestibility. At University Park, Pa., work is under way to develop a standardized chemical test which can be used to predict digestibility and intake. Such a digestibility prediction test has given highly significant correlation coefficients for the grasses, though the residual variation is still too high for precise predictions. Studies on relationship of chemical composition and quality are to be continued and emphasis will be placed on prediction of intake.

4. Growth Pattern of Crested Wheatgrass is Key to Management. A 6-year study at Burns, Oregon, has defined the growth pattern of crested wheatgrass on arid grazing land. Growth is slow in April, speeds up during May, and reaches a peak in early June, after which it declines, terminating in late June or early July depending on moisture. Leaves are about 6 inches long May 1, heads are in the boot in late May and emerged in early June. Anthesis is between June 25 to July 5 and seeds are hard about July 20. Dry matter percentage in the herbage increases from 28% in early May to 74% in late August, and crude protein declines during the same period from 14% to 3%. The maximum per acre yield of crude protein is reached in mid-June. Root growth is very active in April and has stopped by June 1. Carbohydrate root reserves accumulate rapidly in May, and remain relatively high thereafter. Grazed closely in mid-May, the growing point of elongating reproductive culms is removed and their further growth prevented, buds giving rise to vegetative culms are activated, and a new crop of vegetative stems develops. Thus, crested wheatgrass can be grazed throughout the spring season, until no more forage remains, or it can be grazed moderately heavily in mid-May, to activate vegetative stem development, and rested while this new crop is produced, leading to a flexible 2-crop system of use. Both systems are compatible

with the plants' pattern of growth, and accumulation of root reserves to insure sustained vigor. Under the 2-crop system, total herbage yield is about 70% of that obtained by a single complete grazing usually ending in June.

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SEED CROP CULTURE, DISEASES, PHYSIOLOGY
NUTRITION, HARVESTING, AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. Grass and legume seed crops are 10 to 20 percent below national consumption. Importation of seed of many crops is necessary because technology has not been developed to make seed production a profitable farm enterprise. Some excellent forage-crop varieties with a known satisfactory reproduction potential frequently produce poor seed yields, which means high seed costs. Several drought-tolerant and highly nutritious grasses, adapted to the Great Plains, have had limited usage because of the frequent low and erratic seed yields and high priced seed. Declining seed yields frequently occur after seed crops have been grown in an area for a few years, and often force seed growers to terminate their seed production enterprises. Diseases seriously reduce seed yields. Some organisms destroy only the seed or inflorescence, others kill the plant. Research is needed to investigate the factors that are limiting tiller initiation, fertilization, and seed formation and to develop cultural and management techniques including disease control practices that will assure efficient seed production. Fundamental physiological investigations on growth responses of grasses and legumes to various environmental, management, and microclimatic factors are needed to establish the specific requirements for reproduction.

PROGRAM

Grasses and Legumes. The Department has a continuing long-time program involving agronomists, physiologists, and pathologists engaged in both basic and applied studies. Cultural and management studies for forage-crop seeds are underway at Stillwater, Oklahoma; Corvallis, Oregon; Prosser and Pullman, Washington; and Logan, Utah. Physiologic investigations are underway at Lafayette, Indiana, Stillwater, Oklahoma; and Prosser, Washington. Variety evaluation studies are conducted at Shafter, California; Lafayette, Indiana; and Prosser, Washington. Disease investigations are underway at Corvallis, Oregon. All work is conducted in cooperation with the respective State agricultural experiment stations, and the Entomology and Agricultural Engineering Research Divisions.

The Federal scientific effort devoted to research in this area totals 11.5 professional man-years. Of this number 5.0 is devoted to culture, 2.5 to physiology, 1.0 to diseases, 2.3 to variety evaluation, and 0.7 to program leadership.

A contract with the Agricultural Research Centre, Tikkurila, Finland, provides for the evaluation of genetic stability in seed of alsike, red and white clovers produced in different climatic regions of North America. Its duration is 5 years, 1960-1965, and involves P. L. 480 funds for \$77,416.33 equivalent in Finnmarks.

A contract with the Hebrew University, Rehovot, Israel, provides for research to determine the influence of environment on genetic shifts in forage-crop varieties. Its duration is 5 years, 1962-1967, and involves P. L. 480 funds for \$67,696 equivalent in Israeli pounds.

PROGRESS

A. Culture

1. Effect of Date of Planting on Grass Seed Production. The loss of cash income during the establishment of spring plantings has delayed development of the grass seed industry in some of the highly productive irrigated areas. Studies have been conducted at Prosser, Washington, to determine the effects of spring and fall plantings on the reproduction potential of several grass species. Spring seedings of timothy, smooth brome grass, tall fescue, and four wheatgrasses produced small amounts of seed the year of establishment. Crested wheatgrass produced 363 pounds of seed, orchardgrass produced none. All produced their peak seed yields the following year. Fall seedings of timothy, smooth brome grass, and five wheatgrasses resulted in peak yields the following year. Tall fescue and orchardgrass produced some seed the following year but did not reach their peak until the second year. Fall seedings appear to be an ideal time for the establishment of all the cool-season grasses studied except orchardgrass and tall fescue. To obtain maximum seed yields the year following planting, these two species must be sown in the spring. The number of culms per meter of row was highly correlated with seed yield. Weight of 100 seeds and seed per 100 culms had fewer high correlations with seed yield. Intermediate wheatgrass was the only grass with high correlations between the culms per meter, seed weight, and seed per 100 culms.

2. Rate of Planting and Spring Clipping Effects the Seed Yield of Dixie Crimson Clover. The influence of spring clipping on the components of seed yield and quality of Dixie crimson clover is being investigated at Corvallis, Oregon. Planting at low seeding rates increased seed yields without spring mowing. In 1962 the highest seed yield was obtained following mowing of plants 8 to 9 inches in height to 1-3/4 inches on plots planted at approximately 12 pounds of live seed per acre. Stands planted at low rates of seeding yielded highest among the unmowed plots, but less than the mowing treatments X higher rates of plantings. Correlations in-

dicates: (1) mowing to 1-3/4 inches did not influence seed yield or number of heads per square foot but the effect on stem height, number of seeds in 10 heads, and weight of seeds in 10 heads was highly significant; (2) planting rate had a highly significant effect on seed yield, stem height, number of heads per square foot, and number of seeds in 10 heads, and a significant effect on weight of seeds in 10 heads; and (3) planting rate X mowing interaction had a highly significant influence on seed yield, stem height, heads per square foot, and number of seeds in 10 heads, but no effect on weight of seeds in 10 heads.

3. Factors Affecting Alfalfa Seed Yields. Strong interactions among varieties, cultures and years make extrapolation of alfalfa seed yields from one area to another hazardous as shown by a four-year study on alfalfa seed production at Logan, Utah. A co-efficient of variability of 50% or more sometimes occurs in small plot testing for alfalfa seed yields. Many factors affect seed yields some of which are linear, non-linear, and others that interact. A co-efficient of determination of .745 for alfalfa seed production was obtained using 10 linear terms, 3 non-linear terms, and 7 inter-action terms in the model. The more important factors affecting alfalfa seed yields in these tests included soil-moisture-tension, nectar-sugar-concentration, bees-per square yard, racemes per acre X seeds per pod, and chaff X leaf blotch. While the information obtained does not tell what to do to correct the problem of variation in small plot tests, it does explain why it can occur.

4. Harvesting Methods Influence Quality of Smooth Bromegrass Seed. Losses in yield and quality of grass-seed crops are often high when harvested by the direct combine method. Seed shattering in the field before harvest and the heating of seed in storage due to excessive moisture frequently make grass seed production an unprofitable farm enterprise. Studies were conducted at Pullman, Washington, to compare the windrow and direct combine methods of harvesting on seed yield and quality. Seed of Manchac bromegrass was harvested

by simulated-windrow and simulated-combine methods at seed moisture contents ranging from 65% to 12.5%. Seed harvested by the simulated-windrow method was physiologically mature at or above 45.2% moisture content since maximum seed weight, dry weight per shoot, and vigor score were reached at about 45% moisture. Since seed shattering did not begin until the seed had reached 24% moisture, high quality seed was harvested by windrowing well in advance of seed shattering. Seed harvested by the simulated-combine method was not physiologically mature until it had reached about 24% moisture. Although maximum seed weight was obtained at 34% moisture content. Maximum germination in the laboratory, seedling emergence from the soil in the greenhouse, dry weight per shoot, and vigor score occurred at 24% moisture content. The highest quality combine-harvested seed was obtained after shattering had

begun. The results of this study indicate that seed maturation or "after harvest ripening" does occur in immature grass seed which remains attached to the culm until it is air dried.

5. Distribution of Foundation Seed of Forage Species. Distribution of foundation seed of superior forage-crop varieties by the Foundation Seed Project reached an all-time high in 1962. During the year 354,584 pounds of foundation seed were distributed to certified seed growers and seedsmen. This was 113,973 pounds more than the total foundation seed distributed in 1961. Increases in the distribution of foundation Vernal alfalfa, Lakeland and Pennscoth red clovers, and Gahi-1 and Starr pearl millet accounted for a large part of the overall increase. In addition, the Project distributed foundation seed of Atlantic and Narragansett alfalfas, Dollard and Kenland red clovers, Potomac orchardgrass, and Empire birdsfoot trefoil. Also, it makes certain that adequate quantities of foundation Buffalo and Ranger alfalfas are available. A total of 130,398 pounds of foundation Narragansett and Vernal alfalfa, Dollard and Lakeland red clover, and Gahi-1 and Starr pearl millet seed was produced by growers under contract with CCC in Arizona, Idaho, Nevada, and Washington. Plantings for the production of Cherokee alfalfa, a new high-yielding, disease-resistant alfalfa adapted to the Southeast, were made for the first time during the year. The first foundation seed from these plantings will be available after harvest in 1963. The Foundation Seed Project is cooperative among the U.S.D.A., the State agricultural experiment stations, commercial seedsmen, and State foundation seed organizations and seed certifying agencies.

B. Physiology

1. Improved Procedure for Germinating Sand Lovegrass Seed.

Pronounced dormancy in the seed of sand lovegrass (Eragrostis trichodes) constitutes serious problems in evaluating the effect of various seed production practices on this species. The official rules for testing seeds of this species suggest pre-chilling six weeks and the use of KNO_3 for breaking dormancy. Studies were initiated at Stillwater, Oklahoma, to develop a more rapid method for breaking dormancy and to determine the specific requirements for germination and growth of seedling sand lovegrass plants. The results of these studies show that sand lovegrass seeds germinate best in alternating temperatures of 20 to 30° or 20 to 35° C. Pre-chilling the seed at 5 to 10° C. on a substrate moistened with water or a $\text{Ca}(\text{NO}_3)_2$ solution for 14 days effectively breaks dormancy. When KNO_3 was used as a moistening agent during the pre-chill treatments root damage and abnormal seedlings sometimes resulted. Calcium nitrate was found to be less likely to cause root damage than KNO_3 but was equally effective in breaking dormancy. Pre-heating the seed for 40 minutes at 90 to 100° C. combined with the use of a nitrate salt solution is as effective as a 14-day pre-chill treatment in breaking dormancy. However, the studies have shown that the pre-heat treatment can kill non-dormant seeds. The suggested procedure for germinating sand lovegrass seed is: (a) Divide the seed and place one portion in an oven set at 90° to 100° C. for 40 minutes; (b) place samples of the preheated and untreated seed in germination boxes with a 0.2% solution of calcium nitrate moistened substrate; (c) place the seed in a germinator set for alternating temperatures 20 to 30° C.; and (d) discontinue the test after 14 days and report the lot with the highest germination.

C. Diseases.

1. Burning for Grass Seed Nematode Control Injurious to Some Bentgrasses.

Practices for controlling the grass seed nematode in several grass species other than the bentgrasses have been developed at Corvallis, Oregon. These include the disinfection of seed by special seed cleaning processes, burning stubble, and the use of 2-year crop rotations. Grass seed nematode is presently established and causing damage in several new plantings of Astoria and Seaside bentgrasses in the Willamette Valley. The disease does not respond to field burning of Astoria bent and burning is too injurious on Seaside bent. A program to provide nematode-free foundation seed is considered essential to reduce the damage from this disease to bentgrasses. Methods are being explored to achieve this goal.

2. Smut-free Bentgrasses Developed for Foundation Seed Source.

Seed smuts of bentgrasses cause serious losses in seed fields. At Corvallis, Oregon, the smuts were eliminated from stocks of B-11

velvet bentgrass and from Exeter (Rhode Island No. 5) colonial bentgrass. Plantings of these smut-free stocks have been established for the production of foundation seed.

D. Variety Evaluation.

1. Population Shifts in Dollard Red Clover Seed Induced by Environment and Management Treatments. Seed of Dollard red clover produced at Prosser, Washington, and Shafter and Tehachapi, California, and representing increases from different seeding rates, dates of seeding and clipping treatments was evaluated for several vegetative and floral characteristics at Lafayette, Indiana. During the year of establishment each plant was rated for its degree of floral development. The ratings for the various seed lots were compared to ratings for the original breeder seed used to establish the increase blocks. Over all management treatments the seed lots produced at Shafter, California, had the highest floral-type rating, indicating a larger portion of early plants. The seed lots from Tehachapi, California, were next highest while the seed lots from Prosser, Washington, were virtually identical to the breeder seed lot from which the seed increase blocks were established. There was no indication that rate of seeding up to 12 pounds per acre in rows spaced 40 inches apart had any effect on floral-type response of the seed lots. At Shafter, the seedlings made October 1 and December 1 were identical to the original breeder seed. However, seedlings made in February 1 and April 1 resulted in seed lots with higher floral-type ratings than the original breeder seed lots. At Prosser, no differences were observed between seed lots produced the year following a spring or fall seeding. Seed lots harvested in the seedling year at both Tehachapi and Prosser were different from the lots produced from the same stands during the second and third production year. The second and third year production at both Tehachapi and Prosser were virtually identical to the original breeder seed. At Prosser, clipping the seed-production blocks had no effect on flowering type. At Shafter, clipping resulted in seed which was almost identical to the original breeder seed but the seed from unclipped plots resulted in a higher percentage of flowering plants. Winter survival followed inversely the plant-type ratings. At Tehachapi, for example, the progeny of the seedling year harvest had a high percentage of flowering plants but a low winter survival. Likewise, at Shafter, the seed harvested from February and April plantings was lower in winter survival than the seed produced from fall sowings. These results indicate the influence of management treatments and environment on population shifts during the multiplication of cross-pollinated forage varieties. The next generation of seed has been produced at the same locations under similar dates of seeding and clipping treatments and will be evaluated in 1964.

2. Growth Responses of Timothy Propagated at Diverse Geographic Locations. Seed lots representing polycross progenies from each of 4 timothy clones grown at Prosser, Washington; Logan, Utah; Tehachapi, California; and Lafayette, Indiana, were evaluated at Lafayette, Indiana. Individual plants were studied for their date of anthesis, floral development, stem height, disease ratings, and fall growth habit. Floral-stem height analysis showed that the progenies from each of the 4 clones differed but this difference was the same for all locations and years of seed production at the

locations. Date of anthesis, however, showed not only significant clone differences but also differences for locations and location X clone interaction. Progenies produced at Lafayette, Indiana, flowered earlier than those produced at the other three locations. The progenies produced at Prosser flowered the latest. Interestingly, the progenies produced at Prosser and Lafayette during the year in which the vegetative propagations were established did not differ. This would indicate the response of the vegetative plant material to the physiologic conditioning which occurred at Lafayette, Indiana, prior to establishment in nurseries at the Western locations.

3. Experimental Materials for Investigation of Genetic Shifts in Forage-Crop Species. Two hundred sixty-one (261) seed lots representing 37 varieties or experimental combinations of 10 forage-crop species were produced under isolation at Shafter, California; College Station, Texas; Logan, Utah; and Prosser, Washington, as part of the inter-regional study of the effect of environment, culture and management pressures on genetic shifts. Eighteen varieties or experimental combinations were of domestic or Canadian origin, and 19 varieties were part of P. L. 480 projects or informal cooperative projects with European countries. Variables included in the production of the seed lots were generation, day length, temperature, rate of seeding, date of seeding, clipping of initial growth in the spring, and seed harvest at different stages of maturity. Studies to evaluate the influence of these variables on population shifts will be conducted in cooperation with the Indiana Agricultural Experiment Station and originating countries for all the foreign varieties. New plantings were made to produce the second and in some instances the third generation of seed of the 10 species. The information that will be forthcoming from the investigation of the progenies from each generation will aid in developing a more efficient system for the production of forage crops seeds both for domestic usage and export.

4. Evaluation of Grasses for Seed Production Potential. Seed production of many grasses adapted to the Southern Great Plains is often erratic. Nineteen warm-season species were observed

for their seed production potential at Shafter, California, under irrigation to determine whether more intensive studies would be warranted. Sand bluestem, sand lovegrass, weeping lovegrass, sand dropseed, buffalograss, and sideoats grama produced seed yields over 1,000 pounds per acre. Holt Indiangrass and green needlegrass proved to be definitely unsuited to this area for seed production.

5. Evaluation of Seed of Clover Varieties in Finland. The P. L. 480 Project negotiated with the Agricultural Research Centre in Finland provides a long day laboratory for evaluating plant populations from seed lots produced in areas with different environments. During the 1962 growing season evaluation tests were carried out at Tikkurila (latitude 60°) and Maaninka (latitude 63°), using first, second and third generation seed of Finnish varieties produced in the U. S. A. and Canada in 1961. The most detailed work has been carried on with Tammisto red clover. It was found that genetic changes in Tammisto red clover seed lots from the U. S. A. and Canada had been very small. Even in the second and third generations the number of early-flowering plants had increased only slightly or not at all in comparison to the Finnish-grown breeder seed. Similar results were also obtained with 8 lots of first-generation Jo TPA No. 1 tetraploid red clover and 6 lots of Jo TAA-4 tetraploid alsike clover. During the 1962 growing season seed of Finnish clover and grass varieties were produced in the U. S. A. and Canada under the plan of the P. L. 480 Project. Seed of 59 lots of a synthetic white clover variety, representing 6 clones selected at the U. S. Regional Pasture Laboratory and produced at different geographic locations in the United States, were evaluated in 1962 at Tikkurila. In addition, seed of several forage-crop varieties originating in the U. S. was produced at three latitudes in Finland ranging from 60° to 66° . These seed lots will be used in the investigations to study population shifts in varieties when seed is grown under long, intermediate, and short natural photoperiods.

6. The Influence of Environment on Population Shifts in Grass and Legume Varieties. The P. L. 480 Project negotiated with Hebrew University in Rehovoth, Israel, effective August 1, 1962, provides a natural laboratory for evaluating plant populations from seed lots produced at 31° latitude. Two separate isolated seed increase nurseries were established at Rehovoth and Beit Dagan, containing one variety each of alfalfa, birdsfoot trefoil, alsike clover, red clover, white clover, brome grass, and orchardgrass. Seed crops will be harvested in 1964 and 1965. The first generation progenies will be evaluated at Rehovoth, Israel; Tikkurila, Finland; and Lafayette, Indiana, for a number of morphological and physiological characteristics which will indicate the degree of population shifts that occur.

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WEED AND NEMATODE CONTROL
Crops Research Div., ARS

Problem. Weeds cause losses in crops, orchards, grazing lands, forests, water supplies, and irrigation and drainage systems. These losses can be reduced by finding more effective chemical, biological, mechanical and combination methods of weed control.

Plant-parasitic nematodes occur in all soils used for growing of crops and attack all kinds of plants grown for food, forage, fiber, feed or ornamental purposes. Severity of attack by certain fungi is increased if nematodes are present. Nematodes also have been known to be the vectors of several plant viruses. There is need for improvement in methods of controlling nematodes on grain and forage crops.

PROGRAM

Much of the weed and nematode control research in the Department is cooperative with State Experiment Stations, other Federal agencies, industry and certain private groups; and is cross commodity in nature. The total federal weed control program involves 66.5 professional man years' effort. Of this total, 3.9 man years are specifically directed to weed control in grain crops 1.0 in rice; and 23.6 in forage and range plants. The total federal nematode control program involves 21.5 professional man years' effort of which 0.2 are devoted to cereals and 0.8 to forage and range crops.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE
PROGRAMS

A. Weed Control

1. Wheat. Applications of three formulations of 2,4-D at rates varying from 1/2 to 4 lb/A on three dates, a short time before wheat harvest in 1961, did not affect the chemical composition or milling and baking properties of Bison wheat in studies conducted at Hays, Kansas.

2. Corn. Observations at St. Paul, Minnesota, demonstrate that inbred lines of corn with high resistance to corn borer and stalk rot also have high resistance to two triazine herbicides, atrazine and simazine. A naturally occurring chemical in corn plants which detoxifies triazine herbicides is known to impart resistance to insects and fungus diseases.

Addition of a surfactant to prometryne and atrazine formulations increased toxicity of the herbicides in greenhouse and field experiments at State College, Mississippi. Prometryne plus a surfactant reduced the yield of corn in field experiments. At Tempe, Arizona, 2 lbs. of atrazine incorporated into the soil

before planting gave season-long weed control in corn. Preplant and postemergence applications of linuron reduced stands and retarded growth.

At Whiteville, North Carolina, full season control of witchweed was obtained with 2,3,6-trichlorobenzoxypropanol (2,3,6-TBP) at 2 lb/A; 2-methoxy-3,6-dichlorobenzoic acid (dicamba) and 2,3,6-trichlorobenzoic acid (2,3,6-TBA) were also more effective than 2,4-D. All three herbicides were used successfully to increase the time interval between treatments previously required for control of witchweed using 2,4-D. High rates of nitrogen and combinations of nitrogen with 2,3,6-TBA or dicamba gave full season control of witchweed. Most effective time of treatment was 6 to 8 weeks after planting.

A program of catch and/or trap crops in a continuous cultural system for 5 years has been used to deplete the witchweed seed in the soil. However, even after 5 years of a catch and/or trap crop, a few witchweed plants were observed in each plot. Herbicide treatments in crop rotation reduce witchweed and annual weed populations after 2 or 4 years. Residual studies on preplanting soil-incorporated chemicals applied the previous year were conducted with tobacco as the indicator crop. Nine of forty-one chemicals showed formative effects but none very severe.

Viability of witchweed seeds is strongly influenced by temperature during storage, pretreatment, and germination. Four new synthetic compounds were found active in inducing germination of witchweed seeds. A germination inhibitor extracted from witchweed seeds strongly inhibits the effects that the corn stimulant has on the induction of witchweed seed germination. Cotton plants have been found to produce a highly active germination stimulant which apparently has similar chemical properties to the germination stimulant obtained from corn and coleus plants. Concentrates of the natural stimulants have been further purified during the past year. A crystalline material obtained from the stimulant concentrates was inactive as a witchweed seed germination stimulant. Elemental analysis indicated an empirical formula of $C_8H_9NO_2$ and a molecular weight of 151.

Studies on translocation of 2,3,6-TBA applied to corn leaves indicate that the herbicide or an active form of the compound translocates from corn to witchweed where it produces toxic effects on the parasitic plant.

Research dealing with weed control in maize was initiated at several locations in Poland under P. L. 480 project E21-CR-12, FG-Po-140. Progress was made in developing laboratory, greenhouse and field methods for estimating simazine and atrazine residual activity in soils and plants. Increases in potassium ratios in fertilizer treatments increased the resistance of cereals to simazine.

3. Grain Sorghum. Triazine herbicides provided excellent weed control in grain sorghum at Hays, Kansas, and State College, Mississippi. At Hays, sorghum was produced with no cultivation other than the planting operation. Application of 3 lb/A atrazine in August 1961 accomplished weed control until the sorghum crop was harvested in 1962. Chemically treated plots had better stands, more vigorous growth, higher yields, and better weed control than plots which were cultivated. At State College, 2-chloro-4,6-bis(isopropylamino)-s-triazine (propazine), prometryne, and atrazine at 3 lb/A did not injure grain sorghum and gave near perfect weed control. At Hays, for the second year, application

of 3 lb/A propazine preemergence and 3 lb/A atrazine postemergence had no detrimental effect on any of the 10 grain sorghum hybrids. None of 60 genotypic lines of sorghum showed any evidence of damage from these two chemical treatments; however, atrazine applied as a preemergence treatment injured sorghum.

4. Other Cereal Crops. At Tempe, Arizona, good temporary control of wild oats and increased crop yields in barley and wheat were obtained by 4-chloro-2-butynyl m-chlorocarbamate (barban) applications varying from 1/4 to 1.0 lb/A when it was applied while wild oats were about 4 inches high.

5. Rice. Extensive greenhouse and field studies relating chemical weed control to cultural practices in rice were conducted at Stuttgart, Arkansas. Weed infestations were shown to severely reduce yields in rice. Methyl N-(3,4-dichlorophenyl)carbamate (CMPC) at 3 or 4 lb/A applied at time of weed emergence and 3,4-dichloropropanilide (propanil) at 3 or 4 lb/A applied to weed grasses in the 1- to 3-leaf stage were effective for weed control. Irrigation prior to propanil treatments increased susceptibility of weed grasses. Flooding soon after propanil treatment was required to prevent reinfestations by grass weeds. Mixtures of the two herbicides controlled grass weeds better than either herbicide alone where flooding was delayed for 3 weeks after treatment. Rice in the 2- to 3-leaf stage was sometimes injured by CMPC, but usually outgrew the injury soon after spraying.

6. Weeds in Forage Seed Production Crops.

Chemical seedbed preparation was found to be an economical and extremely effective method for establishing new stands of perennial grasses for seed production at Corvallis, Oregon. Seedbeds were prepared in October 1961; germinated weeds were killed by midwinter applications of herbicides; and grasses were seeded in March 1962 without any additional mechanical seedbed preparation. Excellent

stands of grasses free from competing weed vegetation were obtained wherever herbicide treatments gave adequate weed control. Two herbicides, dicamba and prometryne showed excellent selective control of cheatgrass (Bromus tectorum) and rattail fescue (Festuca myuros) infesting bluegrass seed fields of central Oregon. A new herbicide, isocil, shows promise as a more economical chemical for nonselective removal of creeping velvetgrass (Holcus mollis) infesting perennial grass seed fields. Repeat applications of diuron for 4 consecutive years are now beginning to show rather serious reductions in the seed yields of Chewings and creeping red fescue varieties.

DCPA, CDAA, dichlobenil, and nine carbamate herbicides gave 100% control of dodder in greenhouse studies at Prosser, Washington. Five other herbicides provided 80 to 100% control. Field applications of DCPA at 6, 10, and 14 lb/A provided significant but incomplete dodder control in seed alfalfa. Dodder attachment was delayed but not prevented. Alfalfa seed yields in the DCPA-treated plots were more than three times those of the untreated checks in one heavily infested field. Both seedling and established alfalfa tolerated DCPA.

7. Weeds in Grazing Lands

a. Poisonous and Other Herbaceous Weeds

Physiological and Ecological Studies. Degradation of 4-(2,4-DB)-C¹⁴ by alfalfa and birdsfoot trefoil silage was demonstrated under laboratory conditions in New York. Degradation ranged from 13 to 63 percent of the material applied to forage prior to fermentation. Ensiling may be one practical method of reducing residues of some herbicides in forages.

Plants of alfalfa, birdsfoot trefoil, and ladino clover protected from rainfall and sub-irrigated in an open air greenhouse degraded 4-(2,4-DB)-C¹⁴. Twenty-eight days after treatment, the amount of herbicide (C¹⁴) extractable varied from 5 to 15 percent of the quantity applied. Of the forages studied, inactivation of the herbicide was least rapid in red clover. Birdsfoot trefoil degraded the herbicide most rapidly.

Preliminary investigations indicate that 4-(2,4-DB) in the dry state disappears when exposed to sunlight. Disappearance was related to the amount of radiation received. Herbicide applied to glass plates, exposed to sunlight but protected from rainfall, disappeared after 30 days.

Giant foxtail in Indiana is capable of germinating, emerging and producing seed over an entire growing season. Cutting has been shown to be a poor means of control since giant foxtail can reflower

and produce viable seeds regardless of the stage when cut. Numbers of seedheads and seedhead size changed within date of seeding and within stages cut.

In Indiana, time-lapse photography has been shown to be an effective tool in the study of weed competition because it clearly shows the amount, degree and time of natural plant movement. By indicating times of maximal elongation, the arrangement and positioning of leaves, the complexity of light competition can truly be appreciated especially in terms of measuring the environment.

Data taken during six seasons in Nebraska indicates greatest dormancy of buds of ironweed is during the months of August, September, October, and November. Ironweed apparently has no dormancy during the months of March, April, and May. Approximately 60 percent of the buds harvested during the dormant period do not sprout when provided optimum conditions for sprouting. These may be used for studies requiring buds known to be dormant.

Dormancy of buds in ironweed evidently consists of recurring annual cycles of no dormancy followed by absolute dormancy. During the "no dormancy" or "active" stage, buds behave similarly (e.g., none are dormant). Since all buds are active during one part of each year, long-term dormancies such as exist in the buds of certain other species is not present in ironweed. When ironweed stands are clipped during the summer months the response of the axillary bud is related to the height of clipping. When dormancy is only partially established sprouting activity of buds is greater when the stem is cut low than when the stem is cut high. As dormancy becomes more firmly established the length of stem which is allowed to remain is of less importance.

Respiration of small and of large ironweed buds was determined manometrically. Small buds had a higher rate of respiration than large buds. Large buds were less subject to sharp fluctuations than small buds. This was probably because of a smaller ratio of injured to uninjured tissues in the large buds. Additional injury caused by slicing the buds cause an approximate two-fold increase in respiration of large buds and a smaller increase in respiration in small buds. Respiratory quotient (carbon dioxide evolved/oxygen taken up) was 1.06 after 2 hours and 0.86 after 15 hours.

Sprouting of hardshell bulbs of wild garlic from Kentucky and Missouri were nearly identical (30%) during a season in Missouri. Eighty-five percent sprouting occurred with excised primordia from dormant hardshell bulbs of wild garlic indicating that primordia have the potential to sprout but may be blocked by a physical and/or chemical mechanism in the surrounding tissue. Concentrated extracts

of hardshell garlic bulbs decreased growth of plant material in bio-assays indicating the presence of an inhibitor material and/or materials.

Leaf samples of tall larkspur, (Delphinium barbeyi) collected 1, 2 and 3 weeks after spraying with an amine salt of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 2-(2,4,5-trichlorophenoxy) propionic acid (silvex) had much higher concentrations of alkaloids than those of untreated plants in Utah. Plants treated with silvex contained more alkaloids than those treated with 2,4,5-T. Both chemicals have effectively controlled tall larkspur if applied in the late vegetative to very early bud stage of growth.

Snakeweed (Gutierrezia microcephala) has a root system which has a lateral spread which is about four times that of the aerial portions in Arizona. The roots are most common in the surface 6 inches of soil. Dormant buds occur in a band above and below the root crown. These buds grow in the early spring. Older plants dominate the site, causing a stagnate stand; this may account for the sudden disappearance of this short-lived perennial weed without management or control efforts. Control of this weed would mainly shorten the period in which the grasses are suppressed. Also, lack of germination of locoweed, (Astragalus lentiginosus) seeds collected in 1961 may explain the present absence of this weed in areas in which it had formerly been abundant.

Analysis of the data from sampling weed species in Nebraska and construction of frequency distributions from these series of successive samples showed that, (1) stems or plants of weeds per unit area are seldom arranged in a random manner but rather in an aggregated or clumped pattern, (2) using a small sample area on species having such a pattern results in a skewed frequency distribution closely resembling the contagious types of theoretical distributions. These distributions can be made to approach normality by increasing the sample area. An alternate method of normalizing such a distribution is to adjust sample size to a certain range then apply a log or log (N+1) transformation.

Weed Control Studies. For the second year, atrazine at 1 lb/A proved to be the best control for medusahead and also for downy brome in Washington. Best stands of crested wheatgrass (Agropyron desertorum) seeded one year after application of herbicides were also on plots treated with atrazine. Fall application of this herbicide on winter annual grasses was more reliable than spring application.

1,1'-dimethyl-4,4'-bipyridinium salt (paraquat) from 2.8 to 0.7 lb/A cation, when applied at time of spring seeding gave excellent post-emergence downy brome control and was not injurious to seedlings of pubescent wheatgrass in Nevada. Effectiveness of paraquat in

downy brome control at rates of 0.36 lb/A cation and lower was generally increased by late afternoon application as compared with morning application. Paraquat was not effective in downy brome control even at 0.7 lb/A cation without an effective surfactant.

Three chemicals, 2-methoxy-4-ethylamino-6-isopropylamino-s-triazine (atratone), ametryne, and prometone, prevented all seed production of halogeton for two years (1961 and 1962) without serious injury to perennial kochia (Kochia americana) in Utah.

Spraying with silvex or 2,4,5-T at rates of 2 lb/A reduced timberline milk vetch (Astragalus miser var. decumbens) by 99 to 100% during the first year following treatment in Utah. Surviving plants and newly established plants account for less than 1% of the pre-treatment population three years after treatment.

Silvex or 2,4,5-T at 2 lb/A applied once yearly are satisfactory for control of Austrian peaweed (Swainsona salsula) in Washington. Seedling roots of S. salsula were found to grow as much as 10 feet in one growing season.

The most promising herbicide of 15 evaluated on bracken fern in 1962 was dicamba at 8 lb/A in Washington. Also, dicamba has shown selective control of wild garlic in established forage grasses in Indiana and warrants further investigation.

Good to excellent control of most weeds occurring in native grasses in Oklahoma have been obtained with 2,4-D ester at .75 pounds acid per acre applied in May or June. Plants not controlled were ironweed, buckbrush, sumac and skunk brush. One pound of 2,4-D ester per acre in a single or repeated application had very little effect on native legumes such as native lespedeza, yellow neptune, prairie clover, lead plant, wild alfalfa and sensitive briar.

Preemergence treatments with an ester formulation of 2,4-D applied at rates of 1 and 3 lb/A acid during the latter part of March and April gave satisfactory control of western ragweeds, annual broom weeds, yarrow and most all annual broadleaved weeds commonly found in native grass pastures in Oklahoma. The 2,4-D had no residual effect on weeds beyond the year applied.

The satisfactory control of weeds in Indiana in the establishment of forage legumes requires combinations of materials presently available. The choice, rates, and timing of application will depend on weed species, densities and seasonal variation in weather. The use of wetting agents to increase the effectiveness of lower rates of some herbicides appears to be both practical and economical.

EPTC and R-1607 were the only herbicides that gave satisfactory legume establishment in the main legume establishment plots in 1962 in New York. The combination of 4-(2,4-DB) + dalapon was successful in one experiment but not in another. The thiocarbamate herbicides were particularly effective on nutgrass. In Missouri, preemergence applications of diphenamid at 2 and 4 and DCPA at 4, 6, and 8 lb/A controlled weed grasses in seedling alfalfa, but failed to control broadleaved weeds. Diphenamid preemergence and 1 lb/A of 4-(2,4-DB) postemergence controlled all weed species without injury to alfalfa.

b. Brush Control

Physiological and Ecological Studies. Research at Tempe, Arizona shows the visible leaf injury resulting from treatments of 3-phenyl-1,1-dimethylurea (fenuron) on shrub live oak seedlings is not due directly to the depletion of energy supply resulting from inhibited photosynthesis. An alternative hypothesis is proposed, i.e., visible leaf injury is caused by a toxic accumulation product of a fenuron-blocked reaction in the photosynthetic mechanism. A second type of inhibition occurs at high fenuron concentrations and is evident in the inhibition of root growth independent of the photosynthetic inhibition and its toxic accumulation product. Also, only slight difference was found in the development of injury symptoms of leaves of shrub live oak seedlings in low and high humidities. One explanation for this is that upward movement of fenuron is not entirely dependent on transpiration.

Because of evidence that a thick leaf cuticle is one of the primary factors limiting absorption of foliar-applied herbicides, a microscopic study was made of relative cuticle development in outdoor mesquite trees and simultaneously in greenhouse-grown and outdoor-grown seedlings at Tucson, Arizona. Although trees develop a cuticle of 5 microns or more in thickness by the third month following bud-break in March, both greenhouse- and outdoor-grown seedlings of the same age form cuticles which are barely visible under the microscope and only a micron or less in thickness. The study indicates that cuticle development is more a function of plant size or age, rather than whether or not it is grown in a greenhouse or outdoors.

Soluble reducing sugars in the older root tissues of camel's thorn (Alhagi camelorum) fluctuated somewhat in response to the various 2,4-D spraying regimes in different growth stages, but there was no readily apparent relationship between 2,4-D spraying regimes and percent content of reducing sugars in the older roots of treated .

plants in Washington. Percent reserve carbohydrates in the older roots did not vary from untreated plant values regardless of the 2,4-D spraying regime used.

Seed of camel's thorn did not germinate readily without scarification of the seed coat. The optimum germination temperature of scarified seed was near 25° C. About 60 percent of unscarified seed survived 96 hours of stay in the rumen of a fistulated Hereford steer on roughage ration. On a high concentrate ration 80 percent survived 144 hours of stay. Cattle spread camel's thorn.

Soil from near juniper roots inhibit grass growth, but some individual grass plants of each species tested were not effected by junipers at all in Arizona.

Control Studies. Also, in Arizona repeated biannual applications of 2 lb/A of an ester of 2,4,5-T over a three-year period killed over 90 percent of treated shrub live oak plants but repeated annual applications of 2 lb/A of 2,4,5-T over a three-year period did not kill an appreciable percentage of the treated bushes.

Pelleted fenuron at 8 lb/A killed over 80 percent of shrub live oak bushes; at 16 lb/A control exceeded 90 percent. These figures are probably conservative since surviving bushes were at the margins of plots. Lehmann lovegrass re-established itself 12 - 16 months after treatment with 16 lb/A of fenuron.

Preliminary evaluations indicate that dicamba may be more effective as a foliar spray for control of shrub live oak than any of the other herbicides tested to date.

Weight of shrub live oak sprouts after May and June of 1960 top removal was three times as great in August 1962 as when tops were removed in September and October of 1960.

Only a few post and blackjack oak sprouts are appearing on areas in Oklahoma having repeated annual aerial spraying of 2,4,5-T eight to ten years ago which caused 70 to 80 percent kill of small brush and trees.

In Oklahoma, surfactants Tergitol, NPX, Triton X-114 and Emcol H-86C each used in emulsions of the butoxy ethanol ester of 2,4,5-T foliar applied at 2 pounds acid in 5-gallons of water per acre for 2 years caused apparent kill and defoliation of post and blackjack oaks that was equal or slightly greater than that from 2,4,5-T ester in a commercial formulation produced for aerial spraying. Each of three surfactants made up 1% of total spray applied.

Dormant stem spray applications of 2,4,5-T shows promise for controlling sprouts of Gambel oak (Quercus gambelii) in Arizona. By the end of the first growing season following treatment there was an apparent root kill of 50 percent and a stem kill of 92 percent.

Granulated 2,3,6-TBA applied to the soil at the base of alligator, one-seed, and Utah junipers was as good as or better than pelleted fenuron applied at the same rates.

Eight and 16 pound rates of 2,3,6-TBA per acre applied in either the summer or fall controlled camel's thorn in Washington without appreciable reduction in perennial Distichlis stricta and annual Bromus tectorum populations which were of some value for grazing use.

An ester of 2,4-D was slightly more selective for big sagebrush than 2,4,5-T ester. Two lb/A is recommended for the selective control of big sagebrush in bitterbrush stands in Oregon. Delaying spraying progressively from the time of leaf appearance until early fruit development of bitterbrush resulted in greater 2,4-D damage. Spraying at any time killed virtually all leaf tissue and current twig growth of bitterbrush; however, spraying at the time of leaf origin and before the appearance of distinct twig elongation or flowers left only a small amount of dead tissue on large plants. Subsequently, dormant buds initiated new growth and in the autumn only slight evidence of spray injury remained. The amount of growth attained from dormant buds depended upon the duration of favorable growing conditions after spraying. In contrast to large bitterbrush, those less than 12 inches tall were consistently killed.

Comparisons of repeated mowing and spraying treatments for 2 years on buckbrush in late May in Nebraska showed that while mowing gave the appearance of partial control because the old woody stems were knocked down and only recent sprouts or new stems were standing. However, mowing only reduced the stand 24 percent. Spraying with 2,4-D at 1 and 2 lb/A reduced the stand 90 and 92 percent respectively. Spraying with a mixture of 2,4-D and 2,4,5-T at the same rates gave 80 and 86 percent control.

Short leaf pine in Oklahoma that were defoliated or had terminal injury from 2,4,5-T aerial applications recovered the year after being treated and made normal foliage and height growth. Where cone injury occurred following 2,4,5-T applications the seed trees set and produced normal cones the year following the herbicide treatment.

Injector treatments with undiluted triethy amine of 2,4,5-T (4 lb acid per gallon) killed 99 to 100 percent of winged-elm brush and trees in Oklahoma. Control of oak with the same treatment was good, but hickory and ash were resistant to initial treatment and required retreating to obtain satisfactory control.

Defoliation of post and blackjack oaks in Oklahoma with low volatile ester of 2,4,5-T at 1-1/4, 2-1/2, and 3-3/4 lb/A each in 20 gallons of diesel oil per acre were moderately successful. Treatments were applied September 18 to 20, 1962 and defoliated 85, 86 and 96 percent respectively for the rates used. Dinitro and pentachlorophenol at 3, 6, and 9 pints in the same volume of diesel oil was only about 1/3 as effective in defoliation of oaks at 2,4,5-T. Sodium metaborate at 12, 16, and 20 pints each in 20 gallons of water per acre was about equal to dinitro and pentachlorophenol in defoliation of post and blackjack oak. Seven-oxabicyclo-(2.2.1) heptane-2,3-dicarboxylic acid (endothall) at the same rates as sodium metaborate was only about 1/3 as effective as the latter.

B. Nematode Control

1. Forage and Range. At Logan, Utah a method has been developed for screening alfalfa varieties and breeding lines for resistance to the stem nematode (Ditylenchus dipsaci). This involves inoculation of young seedlings, requires a minimum of space and apparatus, and is rapid enough to permit handling a large number of tests in a short time. A method of culturing the nematodes needed for the tests has also been developed.

Tests at Tempe, Arizona, have indicated that the new Sonora variety of alfalfa recently released for use in the southeast has retained all of the root-knot nematode resistance found in its "African" variety parentage. This resistant variety will be useful to include in crop rotations designed to reduce nematode populations.

Experiments at Tempe, Arizona have shown that seedlings of one breeding line of Sirsa alfalfa and 13 breeding lines of African alfalfa are highly resistant to the cotton root-knot nematode and the Javanese root-knot nematode as compared with the Lahontan variety. Resistance of all the African lines was greater than that of the Sirsa line.

The stem nematode (Ditylenchus dipsaci) was found on alfalfa in 4 different field locations in Alabama in 1962, severe losses occurred at one location because of stunting of plants and loss of stand, and localized areas of loss were observed in other locations.

Studies of the stem nematode (Ditylenchus dipsaci) of clover at Puyallup, Washington, showed that the nematode could persist indefinitely in the field, on volunteer plants. The nematode goes in-

to a dormant stage when dried, and remained alive in clover hay stored for 3 years, but not for 4 years. In dried clover seed heads, dormant nematodes were found attached to seed coats by "honeydew" produced by aphids.

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CORN, SORGHUM, AND SMALL GRAIN INSECTS
Entomology Research Division, ARS

Problem: Many species of insects cause losses amounting to millions of dollars annually to corn, sorghum, and small grains. It is estimated that 25 species of insects cause an annual loss of \$900 million to corn alone. The European corn borer and corn earworm are two of the most destructive insects in the country, and corn rootworms are serious pests of corn. Armyworms attack corn and small grains. In certain years the greenbug causes widespread losses to wheat, barley, and oats in the Central and Southeastern States, and the hessian fly and wheat stem sawfly annually damage the wheat crop in certain areas. Recently, the sorghum midge has become a more important pest of sorghum in the Southwest. The cereal leaf beetle, first identified in the United States in 1962 from Berrien County, Mich., now occurs in 46 counties in Michigan, Indiana, and Ohio, and is a threat of unknown proportion to small grain crops. Such examples of the destructiveness of insects to corn, sorghum, and small grains point up the need for extensive research that will lead to the development of adequate means for the control of these important crop pests. Progress has been made toward the solution of some of the insect problems encountered in the production of grain crops but more effective, more economical, and safer insect control measures are needed. Research is essential to find insecticides that can be applied to grain crops, that will not leave residues harmful to animals consuming the feed, that will not be a hazard in milk and meat, and that will not be detrimental to beneficial insects or to fish and wildlife. The appearance of resistance to certain insecticides in several grain insect pests stresses the need for basic information to overcome this problem. Additional emphasis should be placed on research to develop crop varieties resistant to insects and on biological and cultural control methods. New approaches to insect control, such as sterilization techniques and attractants, require expanded investigation. Research is also needed on insect vectors and the role they play in the dissemination of important plant diseases. The heavy losses in oats, wheat, and barley due to barley yellow dwarf virus, and in corn due to stunt diseases recently found in Ohio and several Southern States, indicate the importance of research in this field.

USDA PROGRAM

The Department's program involves both basic and applied research directed toward developing more efficient control methods for insects attacking grain. All studies are conducted in cooperation with State Experiment Stations in the several States where research is underway. Studies on evaluating and developing varieties of grain which resist insect attack are conducted in cooperation with State and Federal agronomists and plant breeders and research on insect

transmission of diseases of grain crops is in cooperation with State and Federal plant pathologists. This research includes studies on hessian fly, wheat jointworm, and cereal leaf beetle at West Lafayette, Ind., and Manhattan, Kans.; aphids and mites attacking small grains at Stillwater, Okla., Brookings, S. Dak., and Tifton, Ga.; wheat stem sawfly at Minot, N. Dak., Brookings, S. Dak., and Bozeman, Mont.; corn earworm at Tifton, Ga., State College, Miss., and West Lafayette, Ind.; fall armyworm, pink scavenger caterpillar, and rice weevil at State College, Miss., and Tifton, Ga.; soil insects attacking corn at Brookings, S. Dak., State College, Miss., and Tifton, Ga.; corn leaf aphid at Brookings, S. Dak.; southwestern corn borer at Stillwater, Okla., and State College, Miss.; European corn borer at Ankeny, Iowa, State College, Miss., and Wooster, Ohio; corn earworm, sorghum midge, sorghum webworm, and corn leaf aphid on sorghums at Stillwater, Okla., and Tifton, Ga.; and insect transmission of grain diseases at Manhattan, Kans., and Brookings, S. Dak. Research to evaluate improved equipment for application of insecticides to grain crops is underway at Ankeny, Iowa, and Tifton, Ga., in cooperation with Federal agricultural engineers. Work on corn rootworms is being conducted at Brookings, S. Dak. Additional research is being conducted under ARS contracts, on the biology and control of the cereal leaf beetle with Michigan State University, and on soil insects attacking corn with the University of Nebraska.

The Federal scientific effort devoted to research in this area totals 36.5 professional man-years. Of this number 9.2 is devoted to basic biology, physiology, and nutrition; 4.5 to insecticidal and cultural control; 3.0 to insecticide residue determinations; 3.6 to biological control; 2.3 to insect sterility, attractants and other new approaches to control; .5 to evaluation of equipment for insect detection and control; 10.7 to varietal evaluation for insect resistance; 1.3 to insect vectors of diseases; and 1.4 to program leadership.

Certain phases of this research are contributing to regional research project NC-20 "Factors Influencing European Corn Borer Populations". A P. L. 480 project, E8-ENT-1, "Population Dynamic Studies on Calligypona pellucida (F.) and the Nature of Injuries Caused by This and Other Leafhopper Species (Fulgoridae) on Cereals, Especially Oats and Spring Wheat" is underway at the Agricultural Research Centre, Department of Pest Investigation, Helsinki, Finland. Another P. L. 480 project, A10-ENT-5, "Host Plant-Vector and Host Plant-Virus Relationships of Rough Dwarf Virus of Corn and Methods for Control of The Disease" is being conducted at the Hebrew University, Rehovoth, Israel. A7-ENT-25 in India is concerned with "Research on Insect Pests of Maize With Special Reference to Stalk Borers."

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Corn Insects. Population studies on European corn borer in Boone County, Iowa, in the spring of 1963 showed that overwintering borers averaged 3,187 per acre. Pupation began May 15, 1963, and first brood oviposition June 2. The population of the first brood averaged 15 borers per 100 plants. The 1962 fall population had averaged 105 borers per 100 plants, and 4833 borers per acre.

Experiments at Ankeny, Iowa, designed to study the factors influencing mating of European corn borer moths indicated that maximum mating (100%) can be obtained in 48 hours under laboratory conditions by alternating temperatures from 85° F. (day) to 65° F. (night), and maintaining a light period of 14 hours in length for each 24-hour period.

A study initiated at Wooster, Ohio, to study single-generation and multiple generation strains of the European corn borer, showed that the diploid number of chromosomes was 62.

Diet and light studies in laboratory tests on the European corn borer, at Ankeny produced the following results: (1) Corn borer larvae reared on artificial media will go into a false diapause if subjected to 13-1/2 hours of light daily. (2) Deterioration of leaf factor materials stored in a refrigerator can be prevented by adding supplementary vitamins. (3) Dietary shortages lead to morphological deformities. (4) A completely defined diet is necessary to study nutritional diseases of the European corn borer.

At Brookings, S. Dak., it was determined that susceptible strains of the southern corn rootworm metabolized aldrin to dieldrin while the resistant strain metabolized aldrin to an unknown compound. The resistant strains required about 3 times as much aldrin as the susceptible for an LD₅₀. The western corn rootworm metabolized aldrin in a similar manner.

At Tifton, Ga., the quantity of Telodrin required internally to produce mortality of first-instar corn earworm larvae ranged from 1.19 to 5.59 p.p.m., and of third-instar larvae, from 5.86 to 6.05 p.p.m.

The corn earworm caused an estimated \$3,100,000 loss to corn in Georgia, Florida, Alabama, North Carolina, and South Carolina, in 1962, and was found in every field examined during a survey in these States. The pink scavenger caterpillar was found in 99% of the fields, the rice weevil in 90%, and the fall armyworm in 5%. In Mississippi over 56% of the ears were infested by the corn earworm, causing an estimated loss of \$543,000. Extremely heavy fall armyworm populations caused

a complete crop failure in late-planted corn. About 89% of the ears were infested with the pink scavenger caterpillar. The southwestern corn borer now occurs in all agricultural districts of Mississippi except the south-central district, infesting nearly 40% of the fields.

In a study of corn earworm larval feeding habits in a resistant (F44 x F6) and a susceptible (Mp316 x Mp319) single cross at State College, Miss., the larvae preferred silks to kernels for food and in some instances chose silks for the entire feeding period. They also fed more on hybrids having high percentages of reducing sugars than on those with low percentages of such sugars.

At Tifton, Ga., measurements of the circadian rhythm of the corn earworm indicated definite periods of night flight that are not dependent on light changes. Photoelectric-photograph analyses of moth flight showed that noctuid moths are much more maneuverable than sphingid moths, with a greater degree of aerodynamic lift at a lower angle of attack. Leg appendages are used for flight stabilization. Antennae are fairly stable in level flight. Noctuid antennae tend to bend under aerodynamic stress, e. g., during loops or steep climbs, while sphingid antennae remain fixed and rigid under the same stress.

At Tifton, Ga., morphological and light trap population studies indicated that the first April-May corn earworm flights are of major economic importance. The early population probably represents an efficient overwintering population since the percentage of mating of this flight is far above the yearly average.

At Stillwater, Okla., the percentage of stalk girdling by the southwestern corn borer was higher and the yield lower in late-planted than in early-planted corn. Also, the percentage of borer girdling and stalk lodging increased and the yield decreased as harvest was delayed. Machine harvesting in infested corn resulted in lower yields than hand harvesting, largely because of the failure of the harvester to recover lodged stalks, the majority of which were girdled by the borer.

In southeastern South Dakota and northwestern Iowa, resistant strains of the western corn rootworm were observed in fields which had been treated with chlorinated insecticides. Some of the strains were 40 times as resistant as the strain collected from untreated areas. Damage to corn by the northern corn rootworm was moderate when larval populations developing to adults numbered 70 per plant.

Adult emergence of the northern corn rootworm at Brookings, S. Dak., extended over a six-weeks period beginning August 1. Maximum emergence occurred August 15-25.

At Brookings, the southern corn rootworm has been reared through six generations in the laboratory. Adult beetles in cages fed on young squash leaves, and on an artificial diet of honeybee pollen substitute, fine corn meal, water, and honey. Oviposition took place on cellulose cotton placed under the cage. Larvae were reared in petri dishes. A generation was completed in about 6 weeks. Eggs of the western corn rootworm held at room temperature for two weeks and at 40° F. for 40 days began hatching after 3 weeks exposure to 86° F., and continued to hatch for over three months. Prolonged refrigeration reduced the hatching period to 45 days. Eggs of this species do not require freezing temperatures for diapause breakage. Five types of plant or synthetic diets which were attractive to beetles were squash leaf, corn silk, corn borer artificial medium, casein-agar base diet with corn silk attractant, and pollen substitute.

2. Small Grain and Sorghum Insects. Tests conducted at West Lafayette, Ind., indicate a buildup of hessian fly (Race B) in the field. This race is capable of infesting W38 derivative wheats such as Monon, Dual, and Reed. With rapidly increasing acreage being planted to these resistant varieties, natural selection may favor the establishment of Race B populations. Two wheats, Lathrop and Knox 62, resistant to Race B, have recently been released.

Studies being conducted at West Lafayette on the inheritance of resistance of PI 94587, a Portuguese durum variety which has thus far remained immune to all known races of hessian fly, suggest that as many as 4 dominant resistance factors may be present in this variety. The transfer of the entire resistance gene complex from durum PI 94587 to common wheat types will be difficult but offers an approach to breeding for resistance to all currently known hessian fly races.

Radioisotope studies at West Lafayette have shown that hessian fly larvae consumed the most food during the fifth to seventh day of feeding and that larval growth was adversely affected by the isotope. Adult mutant forms (males without abdomens and females with growths on the thorax) emerged from wheat plants grown in P^{32} solution.

The reaction of barley plants and greenbug to several plastic materials used in cages was investigated at Stillwater, Okla. Cellulose acetate and vinyl cages killed young barley plants in less than 10 days and had an adverse effect on greenbug development and fecundity. Cellulose nitrate had no adverse effects on plants or insects.

The greenhouse greenbug biotype, which is capable of destroying wheat lines resistant to the normal field strain of greenbug, was found again in the greenhouse at Stillwater, Okla., for the third time in eight years. This strain, however, has not been found in the field.

Studies on the effect of temperature and host plants on fecundity of field and greenhouse biotypes of the greenbug at Stillwater, Okla., indicate that fecundity was not affected in the field biotype when reared on resistant and susceptible host plants at low temperatures, but at higher temperatures fecundity was greatly retarded on resistant plants. Fecundity of the greenhouse biotype when reared on resistant wheat (DS28A) was comparable to that of the field biotype when reared on susceptible plants (Ward barley) at all temperatures, indicating that DS28A wheat lacks resistance to the greenhouse biotype.

At Stillwater, Okla., the fall armyworm caused a yield reduction of 12% in late-planted sorghum, due to a decrease in the number and size of kernels in the infested heads. The corn earworm, southwestern corn borer, fall armyworm, and tobacco budworm have been successfully reared throughout their life cycles on artificial media for use in sorghum insect resistance studies.

At Manhattan, Kans., a study of the wheat curl mite in native or cultivated grasses indicated that grasses are not important in epidemic outbreaks of wheat streak mosaic. Grasses are probably helpful in maintaining endemic populations of the mite, but volunteer wheat is essential for epidemic outbreaks. Size and color of the wheat curl mite may be used as criteria for determining when populations are ready to disperse. Ninety-six percent of the larger (225-230 microns) darker (yellow) mites from the older, dry material became established when transferred to wheat seedlings, as compared with 62% of the smaller (218 microns) lighter colored mites from green, succulent wheat.

Research in Michigan indicated that the cereal leaf beetle has only one generation a year under field conditions. The adult diapause can be broken by artificial cold and under laboratory conditions all stages of the beetle can be made available for study throughout the year.

B. Insecticidal and Cultural Control

1. Corn Insects. Granular formulations which gave satisfactory control of first-brood European corn borer at Ankeny, Iowa, were diazinon, Sevin, endrin, Bayer 44646, Zectran, and Union Carbide 8305. Telodrin was most effective against second-brood borers. Zectran, Telodrin, and endrin in that order were the most effective when applied as a spray. The effectiveness of Sevin spray was increased by the addition of a spreader-sticker (Lovo 192). Systemic insecticides showing promise were American Cyanamid C.L. 47470 and C.L. 47031, reducing corn borer cavities in the stalks as much as 90% in some tests.

Studies conducted at Wooster, Ohio, growing resistant and susceptible single crosses in nutrient solutions, indicated that the level of borer establishment in both broods increased with an increase in phosphorus level. The resistant strain contained somewhat fewer larvae than the susceptible one, the difference being especially apparent in second brood infestation.

Of six insecticides evaluated for control of the corn earworm at Tifton, Ga., Bayer 41831 at 2 pounds per acre, Bayer 44646 at 1 pound, Bayer 47940 at 2 pounds, Zectran at 1 pound, and Telodrin at 1 pound, gave control equal to or better than that obtained with a 1-pound-per-acre application of DDT. Zinophos at 1 pound per acre and heptachlor at 1 pound gave poorer control.

In two experiments at two locations in Mississippi four to six applications of endrin at 0.5 pound per acre, or Sevin at 1.5 pounds per acre, significantly reduced plant girdling and breakage due to southwestern corn borer infestation. Control of the southwestern corn borer in late-planted corn resulted in significantly greater yields ranging from 8-19 bushels per acre. Fall cultural practices affected larval survival of the southwestern corn borer in Mississippi. Larval survival in undisturbed stalks the following spring was 64.3%; in uprooted stalks 4.4%; and in disked stalks 1.1%.

In Mississippi, aldrin at 1 pound per acre applied in a 6- to 8-inch band along the drill row, or at 2 pounds per acre applied broadcast at time of planting, gave better control of soil insects in cornfields the second year after treatment than the first. At Lincoln, Nebr., both phorate and diazinon gave good control of the resistant strain of the western corn rootworm.

2. Small Grain and Sorghum Insects. At Stillwater, Okla., Sevin at 1-1/2 pounds per acre was more effective against the corn earworm in sorghum heads (58% control) than Zectran at 1 pound (46%) and Bayer 37344 at 1 pound (31%). Sevin had the least effect on the beneficial predator, Orius sp. (13% mortality) followed by Zectran (67%) and Bayer 37344 (86%). Sorghum varieties exhibited differential burn reaction when treated with naled at 1 pound per acre, with 64% of the 72 entries showing injury. RS-610 and DeKalb E56a, the varieties used most commonly in previous insecticide spray tests for sorghum insect control, showed little or no burning.

Of seven materials tests against the army cutworm on wheat in Oklahoma, endosulfan (92%), endrin (89%), and Bayer 25141 (81%) gave the best control, although the Bayer compound resulted in some phytotoxic effect when applied to Triumph wheat at 1 pound per acre. In tests conducted at Stillwater against the corn flea beetle dieldrin (95%) and Telodrin (95%) at 1/2 pound, toxaphene (91%) at 2 pounds, and DDT

(94%) at 1-1/2 pounds, gave the most effective control.

In Michigan Sevin at 3/4 to 1 pound per acre gave better control of the cereal leaf beetle on oats than malathion at 1 pound per acre.

Insecticides as foliage, furrow, and seed applications were tested for wheat stem sawfly control at Bozeman, Mont. Heptachlor and heptachlor epoxide applied as furrow and seed treatments at time of seeding gave the best control. Applications were made with a commercial type fertilizer attachment on a press drill or with a single-row belt seeder. Both were effective. Rate of seeding along the margin of wheat strips as a means of decreasing wheat stem sawfly cutting was also studied at Bozeman. The heavier seedings had a lower percentage of cutting in one test but not in another. examination of wheat inside the field next to the heavily seeded rows showed no reduction in amount of sawfly cutting, regardless of seeding rates.

Under low levels of insect and mite populations on wheat subjected to stubble mulch and clean cultivation tillage practices, more army cutworms, brown wheat mites, white grubs, and false wireworms were found in the stubble mulch than in the clean cultivation plots. Populations of the greenbug, apple grain aphid, and English grain aphid were about the same in both tillage practices.

C. Insecticide Residue Determinations

1. Residues on Corn. Corn treated with 1 and 2 pounds of diazinon in granular formulation for European corn borer control, at Ankeny, Iowa, had residues of 8.9 and 23.1 p.p.m., respectively, 2 days after treatment. In 16 days these residues were reduced to 0.1 p.p.m. and 0.4 p.p.m. No diazinon residue could be detected 48 days after application.

Sevin applied as a spray to corn four times, at 4-day intervals, produced residues on the husks 1 day after the last treatment of 38.3 p.p.m. when applied alone, 38.1 p.p.m. when applied with "Plyac" sticker, and 33.2 p.p.m. when applied with "Lovo" sticker. Samples of husks and cobs collected 7 days after the last treatment contained 8.0, 11.4, and 10.4 p.p.m. of Sevin from treatments of Sevin alone, Sevin plus Plyac, and Sevin plus Lovo, respectively. Subsequent fermentation of the corn did not result in an appreciable loss of Sevin.

1-Bromochlordene granules applied to corn plants for control of the first brood of European corn borer at Ankeny, Iowa, at 1 pound per acre left residues of 1.93 p.p.m. and 0.22 p.p.m., 2 and 16 days after application, respectively. The residue of 0.22 p.p.m. remained for 48 days without further decrease.

At Tifton, Ga., sweet corn treated with varying rates of Telodrin was analyzed for residues on different dates after application. Residues on leaf and stalk samples taken immediately after treatment ranged from 8.4 p.p.m. on plots treated with 2 pounds per acre down to 1.9 p.p.m. on plots treated with 0.5 pound per acre. Immediately after treatment residues on the husks ranged from 1.8 to 2.0 p.p.m. Only the 2-pound-per-acre level showed any residue (0.01 p.p.m.) on kernels and cob. Telodrin residues declined rapidly 24 hours after application. No residue was detected on the kernels and cob at any treatment level on the day of application. The residue deposit on leaf and stalk was 8.4 p.p.m., immediately after treatment; after 21 days it was 0.7 p.p.m.

In a study of the persistence of endosulfan on corn plants at Tifton, Ga., 1 pound of endosulfan per acre was applied as an emulsifiable concentrate spray. The initial deposit was about 16 p.p.m., which decreased to about 0.2 p.p.m. after 3 weeks in the field.

D. Biological Control

1. Corn Insects. At Ankeny, Iowa, one application of a granular formulation of Bacillus thuringiensis gave as good control of first- and second-brood European corn borers on field corn as did DDT or endrin, two insecticides recommended for borer control. Control with other formulations was unsatisfactory. A spreader-sticker did not enhance borer control of spray formulations of B. thuringiensis used in multiple applications on sweet corn. Beauveria bassiana and Metarrhizium anisopliae were the most pathogenic of the fungi isolated from dead corn insects. Aspergillus parasiticus and Fusarium neoceras, while less pathogenic, were much more common in the wild populations. Other fungi isolated but less virulent and common were A. niger, A. ustus, Mycodirma clayi, paecilomyces varioti, Penicillium cyclopium, P. decumbens, P. puberulum, Rhizopus stolonifer, and Scopulariopsis brevicaulis, some of which have not previously been reported from insects.

At Wooster, Ohio, predators eliminated approximately one-third of the first-brood and one-fourth of the second-brood borers. Microplitis croceipes was the most important parasite of corn earworm larvae feeding in whorl stage corn at Tifton, Ga. A tachinid parasite of Heliothis armigera, imported from India, successfully oviposited and developed in the corn earworm. Development of this parasite was poor in the armyworm.

Investigations involving larvae, pupae, and adults of Heliothis zea and Spodoptera frugiperda at Tifton, Ga., revealed the presence of a variety of pathological conditions in the absence of etiological agents. Heavy deposits of crystals and crystalloids were seen in the adipose tissue, pericardial cell, and muscle tissue in both hosts.

Hypertrophy and granulation changes were observed in a nuclei of the affected tissues and in their vicinity in a manner suggesting insipient stages of pathological changes. Abnormal tissue formations frequently denoted by intense melanin deposits were diagnosed, especially in pupae. In adults similar symptoms were accompanied by lack of development of ovaria and occasionally anomalous feeding behavior (bloating).

Aldrin, dieldrin, heptachlor, and diazinon had no adverse effect on soil bacteria or nematodes at Brookings, S. Dak., when applied at concentrations up to 1000 times normal field dosages.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Corn Insects. Female fall armyworm moths laid sterile eggs after being individually fed 62.5 micrograms of tepa per moth in a 10% sugar solution. Male moths were sterilized when fed 31.2 micrograms of tepa per moth. No apparent reduction in mating was observed in female fall armyworm moths which were fed 62.5, 125, 250, or 500 micrograms of tepa per insect. However, the frequency of matings per female was reduced. Male fall armyworm moths were sterilized when fed 31.2 and 62.5 micrograms of tepa per moth but were able to mate as frequently as untreated moths.

Only sterile eggs were produced from matings of female and male fall armyworm moths fed on a 1% honey solution which contained 1 mg. of apholate per ml. Apholate reduced egg production by fall armyworm moths which emerged from pupae dipped in water solutions containing 1 mg. of apholate per ml. However, the eggs deposited by these moths were viable. Unmated fall armyworm moths, 3, 4, 5, and 6 days old were fed for 24 hours on a 10% honey solution containing 0.5 mg. of apholate per ml. None of the eggs produced after mating were viable. On the other hand viable eggs were produced by 1- and 2-day-old moths fed the solution and by moths fed immediately after emergence. Continuous exposure of fall armyworm moths to a solution of 1 mg. of apholate to 1 ml. of honey, practically eliminated egg laying. The frequency of mating was reduced by 64%.

Progress is being made in the field of attractants. At State College, Miss., an extract from frozen vapor collected from a freeze-dry apparatus in the lyophilization of fresh corn silks proved to be an attractant to corn earworm larvae. However, it had no effect on the adults. At Brookings, S. Dak., a feeding arrestant was extracted from corn leaves which when added to cellulose-cotton caused northern and western corn rootworm beetles to feed on the material. At Ankeny, Iowa, an ether extract of tips of abdomens of mating pairs of corn borer moths was an effective sex (male) attractant in small cage laboratory studies.

F. Evaluation of Equipment for Insect Detection and Control

1. Corn Insects. Sticky-board surfaces covered with an adhesive, "Stickem", on cylindrical drums held on vertical poles at 3-, 6-, 9-, and 12-foot levels, effectively trapped adults of the northern corn rootworm and provided evidence that flight of most beetles in growing corn in late August occurred below the 6-foot level. The trap appears promising for the detection and measurement of adult populations of corn rootworms.

Agricultural engineers and entomologists at Tifton, Ga., found that plants dusted with an electrostatic duster, producing both positively and negatively charged particles, had about 57% and 36%, respectively greater residues than plants dusted with uncharged particles, even 48 hours after application. The positively charged dusts in general produced slightly higher residues than the negatively charged dusts. These researchers also determined that superior spray coverage and corn earworm control could be obtained when sprays were applied at 100 p.s.i. with fan type nozzles placed 90° to the plant. Methylene blue was a satisfactory dye for use in a study of spray residue deposit.

At Brookings, S. Dak., a method of extraction of rootworm eggs from soil was devised, utilizing a flotation technique. A soil sample is placed in a container of concentrated sugar solution and agitated briefly by a magnetic stirrer. The debris floating on the surface larger than rootworm eggs is removed with a screen. The remaining debris is washed onto filter paper in a bucher funnel, and the excess water removed. The filter paper is then examined under a dissection microscope for the eggs. All stages of the rootworm float readily in concentrated sugar solution without any apparent ill effects. Use of a ratio of 1 part soil sample to 4 parts of a 2.6 molar sugar solution, with an agitation time of 3 minutes and a flotation time of 5 minutes, provides a suitable means for recovering 85% of the rootworm eggs in a sample of sandy loam soil.

2. Small Grain Insects. Under conditions prevailing in South Dakota during the spring of 1963, yellow pan traps were nearly useless for detection of grain aphid flight activity. Grain aphids were repeatedly taken in wind traps during April and May while yellow traps were apparently unattractive. Beginning early in June, yellow pans began to yield specimens of the grain aphid.

G. Varietal Evaluation for Insect Resistance

1. Corn Insects. One-hundred and forty-three inbred lines of corn submitted from State and Federal agencies associated with the Southern Corn Improvement Conference area were evaluated at Ankeny, Iowa, for first-brood European corn borer resistance. Fifteen percent of the

entries were rated as highly resistant, 60% were intermediate, and 25% were susceptible.

Studies conducted at Ankeny, Iowa, on factors affecting stalk lodging (and harvest) as measured by crushing strength indicated that as the mean corn borer infestation, stand, and nitrogen application increased, the crushing strength decreased.

Progress in the development of corn borer resistant hybrids during the past decade was studied at Ankeny, Iowa, by comparing a group of old and new hybrids. On the basis of differences in yield between the treated and infested split plots, three hybrids extensively grown 10 years ago (Ia.4297, Ia.4417, and US.13) lost an average of 13.8 bushels per acre as a result of corn borer infestation. Five of the newer hybrids (Ia.5036, Ia.5087, Ia.5063, AES.514, and AES.704) lost an average of only 4.6 bushels per acre. Stalk breakages for the older and newer hybrids were 15.2 and 2.0%, respectively.

At Ankeny the Iowa inbred B52 was the most resistant line to second brood European corn borer. Released inbreds R101, R181, B51 and an experimental WF9 recovery also exhibited a very satisfactory degree of resistance. Lines classified as having intermediate resistance were B14, B53, B54, B55, B57, and B50.

At Wooster, Ohio, inbred lines of dent corn, submitted by corn breeders from the Northern States of the North Central Region were evaluated for corn borer resistant germ plasm. Many inbred lines from the Michigan Agricultural Experiment Station, some reciprocal recurrent selections out of double crosses, and some derivatives of crosses between susceptible and resistant lines and brachytic and prolific segregates, had a good degree of resistance. Eighteen hybrids, primarily experimental double crosses, also had a good level of resistance.

At State College, Miss., quality or quantity of 20 protein amino acids was not associated with resistance in the resistant dent corn cross (F6 x Mp426), an intermediate dent corn cross (Mp426 x Mp319), and a susceptible dent corn cross (Mp317 x Mp319). The concentration of non-protein amino acid was associated with resistance, being lower in the resistant cross, and higher in the susceptible cross.

Experimental dent corn hybrids and commercial hybrids, from Mississippi, Louisiana, and Texas showing promising corn earworm resistance, are Dixie 18, La. 521, Coker 67, Delta 8812, Keystone 257, Coker 811, Asgrow 500, Texas Experimental 6001, Ala. 8456, and Ala. 8471. Yellow inbreds with a high degree of resistance to the corn earworm in other experiments were as follows: Mp440, LSc 64, L699, and the Texas inbreds 529, 601, and 325.

At State College, Miss., a two-inch husk extension over the tip of the corn ear was sufficient to give protection from the corn earworm. Husk extensions over 2 inches offered no additional protection.

Hybrids that have shown a high degree of resistance to the southwestern corn borer in Mississippi include Pioneer 8218, Funk G 795W, Delta 9907, and the single crosses Mp202 x Mp428 and Mp202 x Mp210.

In Mississippi, it was determined that rice weevil infestation in a cornfield was associated with insect migration and source of infestation. Some of the more resistant rice weevil hybrids which have been tested are: Miss. 6133, DeKalb 1225, Keystone 257, Dixie 82, McNair 444B, Coker 71, Pfister 750, DeKalb 1240, Dixie 18, Pioneer 309B, Pfister 653W, and Dixie 55.

At Tifton, Ga., bioassay of extractions of freshly harvested plant material have indicated that corn silks and leaf tissue vary in susceptibility and resistance to fall armyworm and corn earworm feeding. Inbreds with foliage resistance against the fall armyworm do not necessarily have resistance against the corn earworm.

A technique has been developed at Ankeny, Iowa, for determining quantitatively the presence of 6-methoxybenzoxazolinone in corn inbreds. This procedure involves the use of C¹⁴-labeled 6-methoxybenzoxazolinone. With this technique a near-perfect correlation between 6-methoxybenzoxazolinone and field evaluations of resistance of corn inbreds to the European corn borer was obtained.

2. Small Grain and Sorghum Insects. In field tests conducted at Stillwater, Okla., five greenbug resistant F₈ wheat selections yielded about 28 bushels per acre while the susceptible check, Ponca, was completely destroyed. Infested resistant crosses showed a loss of 0 to 4 bushels per acre over non-infested resistant crosses, due to greenbug feeding. Of 19 barley lines infested by the greenhouse (virulent) greenbug biotype, 17 appeared to have a high degree of resistance. Notable among these were Kearney, C.I. 7580, Dobaker C.I. 5238, Omugi C.I. 5144, and Chase C.I. 9581. Three rye selections from Argentina designated as AR-1, AR-3, and AR-4, showed almost complete immunity to this greenbug strain. No wheat selections have been found with any degree of resistance to this biotype.

Cooperative research with wheat breeders in several States was continued to develop hessian fly-resistant wheats under leadership of the West Lafayette, Ind., station. Over 15,000 lines, hybrids, varieties, and selections were evaluated. Seventeen fly-resistant varieties are now recommended and grown in the United States. Fly-resistant wheats, Reed (C1 13513) and Knox (C1 13701), which obtain their resistance from W38 (H₃) and Pl 94587 (H₆), respectively, were

released by the Purdue University Experiment Station in 1962. It is estimated that 4-1/2 million acres of hessian fly-resistant wheat were grown in 1961-62. Progress has been made in the development of wheats which have combinations of one or more types of resistance, namely, Kawvale, Marguillo, W38, PI 94587, and Ribiero. Multiple resistant type wheats are needed to prevent or slow down the development of new hessian fly races in the field.

Monosomic analysis, using Chinese monosomic plants, indicated that chromosome 5A(IX) is responsible for the single gene resistance of PI 94587 derivatives.

Forty-five selections from the barley backcross Besert x $\frac{4}{3}$ Decatur obtained from Beltsville, Md., were tested at West Lafayette, Ind., for resistance to Race A hessian fly. These backcross lines have continuously shown a high type of resistance. One hundred and sixty-one Purdue winter barleys having fly-resistant parents were also tested to Race A. Seventy-one promising selections were saved for further selection or crossing in Uniform Wheat Nurseries.

Several hundred selections of wheat, oats, and barley were rated for resistance to the cereal leaf beetle. Some differences were observed in them and one selection of wheat (Triticum persicom var. fulginosum) was almost immune. There appeared to be a positive correlation between resistance and the amount of pubescence on the leaves.

Studies on wheat stem sawfly resistance were conducted in cooperation with wheat breeders of the Cereal Crops Research Branch, Crops Research Division, entomologists and plant breeders of the Montana and North Dakota Experiment Stations, and the Science Service Laboratories of the Canada Department of Agriculture.

Tests conducted at Minot, N. Dak., on varieties from the World Collection have revealed no new sources of resistance to the wheat stem sawfly. Several thousand F₃ and F₆ hybrid selections from the North Dakota breeding program were evaluated and reselected on the basis of agronomic qualifications and reaction to sawfly and rust. Selection 57-134, a very promising product of the North Dakota program, was disqualified as a potential sawfly-resistant variety by its poor agronomic performance. Selection 60-54, from the cross 51-3549 x II-50-17, is now considered to be the most promising sawfly-resistant selection.

In the International Sawfly Nurseries, several varieties and advanced hybrid selections from the breeding program of Canada, Montana, and North Dakota, exhibited a degree of sawfly resistance equal or superior to that of the resistant Rescue check. Some solid-stemmed

Rescue-N1315 x 1315 x Golden Ball hybrids (possessing a type of stem solidness different from that of Rescue) and Thatcher x Rescue hybrids, have shown particular promise.

Preliminary studies at Brookings, S. Dak., indicate that the solid stem sawfly-resistant wheat Rescue developed hollow stems when grown under a short length day at a moderately high temperature. The normal solid stems developed when the wheat was grown in growth chambers programmed for an 18-hour day and moderate temperature.

At Tifton, Ga., 59 of 192 grain sorghum lines screened for resistance to the grain sorghum midge exhibited resistance in varying degrees, and at Stillwater, Okla., differential reaction to corn leaf aphid was observed among sorghum varieties, with DeKalb, Plain-swan, and DeKalb Shorty 50 having the lowest populations of the insect.

H. Insect Vectors of Diseases

1. Corn Insects. A plant virus believed to be previously unknown was studied for comparison with other related viruses. The virus, which has been designated Pumpkin Mosaic Virus, or PMV, was effectively transmitted by the striped cucumber beetle, northern corn rootworm, southern corn rootworm, western corn rootworm, and a grasshopper, Melanoplus differentialis. Possible transmission was also observed by three aphid species.

Root-rotting fungi have been associated with corn rootworm feeding injury. They have been isolated from rootworms and from rot-damaged roots. In pathogenicity tests conducted in the greenhouse on representatives of fungi isolated, none were highly pathogenic under the conditions of test but most of the isolates did produce some degree of rotting.

In Rehovoth, Israel, (P. L. 480 project, A10-ENT-5) the planthopper, Calligypona marginata, was discovered to be the vector of the rough dwarf virus disease of corn. This disease has caused serious damage to corn in countries bordering the Mediterranean Sea but does not occur in the United States.

2. Wheat Insects. The wheat curl mite, vector of the wheat streak mosaic disease, was not a problem in 1963. Little mosaic virus was present on volunteer wheat and the mite vectors present were late in dispersing, so that the mosaic that was transmitted to the wheat crop caused little damage.

In Helsinki, Finland, (P. L. 480 project, E8-ENT-1) it was established that Calligypona pellucida females caused toxic injury to hosts, the amount of injury and abundance of leafhoppers being positively

correlated. It was also established that C. sordidula causes a kind of damage to oats which resembles a virus type of disease. Of the C. pellucida vector females proved considerable more effective in spreading the virus than males.

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RICE INSECTS
Entomology Research Division, ARS

Problem: A number of insects including leafhoppers, the rice stink bug, and rice water weevil, seriously damage rice in the several rice-growing areas of the United States. More information is needed on safe, effective chemical-control methods, and on cultural-control methods, to destroy these pests and reduce the damage they cause. Additional emphasis should be given to new approaches to control rice insects. Rice varieties need to be evaluated for resistance to major rice insects. The discovery of hoja blanca, a virus disease of rice, and its insect vector, a planthopper, in the commercial rice-growing area of Louisiana, has greatly intensified the need for more information on the biology, ecology, and control of the vector, and on its relation to transmission of the virus.

USDA PROGRAM

The Department's program on rice insects involves entomologists, agronomists, plant breeders, and plant pathologists engaged in both basic studies and in the application of known principles to the solution of growers' problems. The research is being conducted at Baton Rouge, La., in cooperation with the Louisiana Agricultural Experiment Station. Some of the lines of work have been underway for only a short period of time.

The Federal scientific effort devoted to research in this area totals 2.2 professional man-years. Of this number 0.3 is devoted to basic biology of the leafhoppers, rice stink bug, and rice water weevil; 0.3 to insecticidal control of rice stink bug and rice water weevil; 0.2 to insecticide residue determinations on rice; 0.2 to varietal evaluation of rice for resistance to stink bug, rice water weevil, and vectors of rice diseases; 1.0 to insect vectors of hoja blanca and 0.2 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology and Nutrition

Rice stink bugs (Oebalus pugnax) were reared from the egg to adult on rice seedlings in the laboratory at Baton Rouge, La. Mating was observed but no eggs were laid, indicating that while rice seedlings are adequate for maintenance and growth of the stink bug, they are apparently nutritionally inadequate for egg production.

At Baton Rouge, studies were made of external morphological characters that might be used for determining the sex of rice water weevils

(Lissorhoptrus oryzophilus). The most useful character found was the curvature of sternites 1 and 2. These sternites in the male are concave at the midline; in the female they are convex. The fifth sternite has a raised area that covers more than half the sternite in the female but less than half in the male; the posterior border is curved in the female and straight in the male.

The rice delphacid, Sogata orizicola, can live as long as 13 days without feeding on the rice plant if supplied with water. At a temperature of 80° F. and a relative humidity of 100%, the insects lived less than 10 hours; at 60° F. all insects died in 20 hours. Brachypterous (short wing) females lived longer than alates (winged), and females lived longer than males in all tests.

B. Insecticidal and Cultural Control

In field studies with insecticides at Baton Rouge, La., Sevin at 0.8 pound per acre, methyl parathion at 0.25 pound, and Bidrin at 0.25 pound, gave good control of the rice stink bug. Methyl parathion at 0.125 pound per acre also gave adequate control in most tests.

At Baton Rouge, seed treatment with 4 ounces of aldrin per 100 pounds of seed gave good control of rice water weevil. In field experiments, no damage to seed germination was found with application rates up to 1 pound per 100 pounds of seed. The fungicide, Panogen, caused a decrease in percentage germination when applied at 1 ounce per bushel of seed. There was also an interaction of fungicide and insecticide at higher rates of application. At rates of 1 pound of aldrin per 100 pounds of seed and 1 ounce of Panogen per bushel, germination was reduced by 70%. Panogen alone at this rate reduced germination only 26% and aldrin alone was not phytotoxic.

Insecticides were tested in the greenhouse at Baton Rouge for control of the rice delphacid, Sogata orizicola. Menazon 70% wettable powder applied as a seed treatment at a rate equivalent to 1 pound per 100 pounds of seed gave 100% control at 8 days after planting, 84% after 14 days, and 17% after 22 days. There was apparently no reduction in seed germination. This is the only seed treatment tested that appears promising for leafhopper control. Isolan applied as a spray at a rate of 1/2 pound per acre and Dimetalin at a rate of 1 pound per acre gave good control up to 20 days after treatment. Isolan applied as a flush treatment to pots of rice in the greenhouse at a rate of 1/2 pound per acre and Bidrin at a rate of 2 pounds per acre gave good control of the insects for 14 days, and partial control up to 21 days following application. Phorate and Di-syston applied as granules at a rate of 2 pounds of insecticide, and Dimetalin at 1 pound, per acre gave good control of the rice delphacid in the greenhouse for 30 days. Bayer 25141 in the initial phase of testing also showed promise as an insecticide for control of leafhoppers.

Insecticidal control of the green rice leafhopper, Draeculacephala portola, was also studied. Phorate and Di-syston applied at a rate of 2 and 4 pounds per acre at the first flood or 2 pounds per acre at the second flood, gave good control of the leafhopper. No differences in yields were associated with the different treatments.

C. Insecticide Residue Determinations

At Baton Rouge, La., in a cooperative study with Pesticide Chemicals Research Branch, rice seed treated with aldrin lost about 40% of the insecticide during presprouting operation, probably in the water used to soak the rice grains. This might explain why fish and crayfish are sometimes killed in streams and ponds used to soak rice seed prior to planting.

Analysis made of duck which had been fed 50 mg. of technical aldrin in gelatin capsules, and killed 48 hours later, showed that the oil gland had 120-230 p.p.m. of dieldrin, the body fat 60-280 p.p.m., and skin fat 7-132 p.p.m. The remaining tissues had less than 30 p.p.m. of dieldrin.

D. Varietal Evaluation for Insect Resistance

Greenhouse studies were made at Baton Rouge, La., on preferential egg deposition by Sogata orizicola on various rice varieties. The variety, Dina, was less acceptable for oviposition than Bluebonnet 50, Gulf Rose, or BG-79.

E. Insect Vectors of Disease

The insect vector of hoja blanca, the rice delphacid, Sogata orizicola, was found on 34 properties in 7 parishes of south Louisiana during 1962. All of the infested fields were treated with insecticides, phorate, Phosdrin, or a DDT-malathion mixture by the Plant Pest Control Division. Subsequent surveys for insect vectors at the end of rice harvest in these fields were negative. No hoja blanca was found. A single specimen of Sogata was recovered in rice on Kramer Island, Palm Beach County, Fla., on June 18, 1963.

A new method was developed for screening insect transmitters for a greenhouse colony, using plants 4-7 days old (about 3-leaf stage). Symptoms of hoja blanca develop in infested plants in 4-11 days following exposure to insects. Techniques used previously required 1-5 weeks for symptom development. With the new technique nymphs are used instead of adults, permitting controlled mating of known transmitters. This technique had made possible the selection of laboratory populations with 80-95% of the individuals capable of transmitting the hoja blanca virus.

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FORAGE AND RANGE INSECTS
Entomology Research Division, ARS

Problem: Numerous insect pests that attack forage and range plants in various parts of the United States lower seed production, reduce the quantity and quality of forage crops, and decrease the abundance of range plants for the grazing of livestock. Certain insects are involved in the transmission of forage-crop diseases. Among the more important insect pests are grasshoppers, lygus, and stink bugs, the alfalfa weevil, root borers, spittlebugs, and a variety of aphids including the spotted alfalfa aphid. A variety of insecticides is used to control these insects but they are often costly and may create residue hazards in meat and milk as well as adversely affect wildlife. There is great need for more efficient insecticides that can be applied on forage crops and range vegetation without leaving residues harmful to man or animals or that might harm bees and other pollinating insects. Increased attention should be given to the development of nonchemical control methods. The search for insect parasites, predators, and pathogens and ways to employ them effectively should be emphasized in research. The development of crop varieties which resist attack by insects offers economical and safe insect-control procedures. Forage crops should be evaluated for resistance to major insect pests and resistant germ plasm should be made available for use by the plant breeders in crop-improvement programs. Basic studies are also needed on the feeding habits of grasshoppers under different environments that affect the abundance of these insect pests. New approaches to control of forage and range insects, such as sterilization techniques and sex attractants, should be investigated.

USDA PROGRAM

The Department has a continuing long-term program of basic and applied research on forage and range insects. Studies on varieties of alfalfa resistant to insects are cooperative with State and Federal agronomists and plant breeders, those on plant disease transmission by insects with plant pathologists, and research on insecticide residues with chemists. Grasshopper research at Bozeman, Mont., Mesa, Ariz., and Columbia, Mo., is cooperative with the respective State Experiment Stations. White-fringed beetle research is conducted at Floral, Ala. Biological control studies on armyworms and cutworms at Baton Rouge are cooperative with the Louisiana Experiment Station. Investigations on alfalfa insects are being conducted at Mesa, and Tucson, Ariz., Lincoln, Nebr., and Beltsville, Md., in cooperation with the Experiment Stations in these States. Work on white grubs at Lincoln, Nebr., is cooperative with the Nebraska Experiment Station. Research on clover and grass insects at Forest Grove, Oreg., is conducted in cooperation with the Oregon

Experiment Station. Work on grass insects, plant disease transmission by insects, and insecticide residues at Tifton, Ga., is cooperative with the Georgia Experiment Station. Studies on varietal resistance, insect vectors of plant diseases and grass insects at University Park, Pa., is cooperative with Experiment Stations in 12 Northeastern States. Certain phases of the research on forage and range insects are contributing to regional projects W-37 (Natural Factors Responsible for Grasshopper Population Changes), NC-52 (Factors Influencing the Distribution and Abundance of Grasshoppers), W-74 (Seed Chalcids Attacking Small-Seeded Leguminous Crops) and S-55 (Alfalfa Insects).

The Federal scientific effort devoted to research in this area totals 26.9 professional man-years. Of this number 4.0 man-years are devoted to basic biology, physiology, and nutrition, 5.0 to insecticidal and cultural control, 5.3 to insecticide residue determinations, 3.9 to biological control, 0.8 to insect sterility, attractants, and other new approaches to control, 0.5 to evaluation of equipment for insect detection and control, 5.3 to varietal evaluation for insect resistance, 1.0 to insect vectors of diseases, and 1.1 to program leadership.

A P. L. 480 project, (E21-ENT-9), "Insect Vectors of Virus Diseases of Various Forage Legumes" is underway with the Research Institute of Plant Protection, Poznan, Poland.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Grasshoppers. Extended drought and scarcity of succulent vegetation in Arizona from mid-spring to the end of 1962 were unfavorable to the desert grasshopper, Trimerotropis pallidipennis pallidipennis. The second generation that usually develops in late summer or early fall did not occur in 1962. Hatching of the first generation was irregular and extended from February to early April. Nymphal growth was retarded by unusually moist cold weather. Adults first appeared in early April and by mid-May all specimens observed were adults. There was very little egg development in adult females until early October. No nymphs and extremely few adults of the 1962 hatch were observed during the winter of 1962-63. Hatching of the first 1963 generation began about February 15 and progressed rather uniformly through early March. Some nymphs had reached the fourth instar by March 11-12. In April 1963, the average population was 0.07 per square yard compared with 0.20 in 1962. The decline was caused mainly by dry conditions in nonirrigated land where there was no second generation in 1962.

In alfalfa fields in south-central Arizona the average grasshopper population in April 1962 was 0.42 per square yard compared with 0.17 per square yard in 1961. The migratory grasshopper, Melanoplus sanguinipes, was dominant. The average summer population of this species during July and August 1962, was 0.25 per square yard as compared with 0.17 in 1961. The migratory, desert, and differential grasshoppers were the leading species in the summer survey. In April 1963 the average population was 0.28 per square yard, a noticeable reduction from that in April, 1962. The migratory grasshopper comprised 94% of the grasshoppers collected.

In late June 1962 heavy populations up to 45 per square yard were found in range meadows, alfalfa, and small grain fields in high-elevation areas in eastern Arizona. Plant damage ranged from 25 to 50%. Important grasshopper species were Camnula pellucida, Melanoplus bivittatus, and M. femur-rubrum. No internal parasites were found in samples of adults examined during 1962.

Grasshopper populations in four range plant habitats at Peeples Valley, Ariz., averaged 0.77 and 0.61 per square yard in June and July 1962, respectively, compared with 4.0 and 1.91 in 1961. The decrease was coincident with severe drought and very poor and closely grazed vegetation in the spring and much of the summer of 1961. Populations differed very little in forbs, mixed grass and forbs, grass, and Juncus meadows.

On range-recovery plots in Arizona, the average square-yard grasshopper numbers on a sparse grass area for April-July 1962, in fenced and grazed untreated plots were 1.9 and 1.8, respectively. Green plant conditions favored greater grasshopper development than in 1961. By mid-July the percentage of blades eaten by one grasshopper per square yard in the fenced plot was 18.0, as compared with 12.3 in 1961. Leading species were Aulocara ellioti and Hadrotettix trifasciatus. In a good grass area with good management practices, the average grasshopper populations in fenced and grazed check plots were 1.7 and 3.3 per square yard, respectively. In mid-August a peak number of 8 grasshoppers per square yard occurred in the grazed area, owing to a good hatch of summer species and second-generation Melanoplus sanguinipes. Dominant grasshoppers were Psoloessa delicatula and Eritettix variabilis in the ungrazed plot and P. delicatula, M. sanguinipes, and A. ellioti in the grazed plot.

Tests in a screened insectary without temperature control at Mesa, Ariz., indicate that eggs of the differential grasshopper may hatch without exposure to low temperatures. Some of the eggs that were laid in March and April hatched in June. They were kept over moist sand in salve tins. Daily minimum temperatures during the incubation period ranged from 47° to 74°F.; maximum temperatures, 68° to 105° F.

Females of Melanoplus sanguinipes in insectary cages oviposited readily in sand moistened with water to 25, 50, 75, and 100% of saturation but did not lay eggs in air-dry sand when moist sand was available. This species was reared through 6 generations under laboratory-insectary conditions. More than 86% of the eggs of the sixth generation hatched, and the nymphs and adults were apparently normal in size and vigor.

Experiments conducted at Bozeman, Mont., showed that Melanoplus sanguinipes and M. bivittatus are extremely sensitive to the sterol content in their food. When the artificial diet was prepared with lettuce extract but without cholesterol, none of the test insects completed more than two of the normal five molts. Two analogs of cholesterol, cholesteryl acetate and dihydrocholesterol, were partially utilized as a sole sterol source. Diets containing these two analogs resulted in 10% of the test insects reaching adulthood versus 90% for a control diet containing cholesterol. However, cholesteryl chloride, a cholesterol analog having anti-cholesterol effects in some animals, was not utilized.

Subsequent tests were undertaken to see whether or not cholesteryl chloride would inhibit cholesterol utilization in Melanoplus. The artificial diet was prepared using the original amount of cholesterol and an equal amount of cholesteryl chloride. There was no detectable inhibition of growth in insects fed the diet containing cholesteryl chloride. The cholesterol could be reduced by three-fourths without inhibiting growth. This smaller amount was then used in a 1:1 ratio and a 1:10 ratio (cholesterol:cholesteryl chloride). The amount of cholesteryl chloride made little difference in the results and it was concluded that utilization of cholesterol was little influenced by cholesteryl chloride.

Investigations were continued at Bozeman, Mont., on the ecology of the grasshopper, Hesperotettix viridis, on Montana rangeland. Field observations indicated that hatching began in mid-June and continued until mid-July. Adults were found by mid-July. Mating began the first part of August and continued through September. Nymphs and adults were confined to areas containing numerous plants of snake-weed, Gutierrezia sarothrae. However, even in areas of heavy snakeweed concentrations the grasshoppers did not spread over the entire area but remained concentrated near the hatching places. Field-collected nymphs of all instars were successfully reared to adults in laboratory cages using clippings of snakeweed for food. The nymphs and resulting adults fed mainly on the leaves and blossoms but would eat the bark if fresh food was not available. Also, dried clippings of snakeweed were accepted as food by older nymphs and adults.

Viable eggs were obtained from laboratory cultures of Hesperotettix viridus. Nymphs hatching from these eggs were successfully reared to adults on a diet of snakeweed branches and powdered snakeweed incorporated in an artificial media. Under laboratory conditions the average time from hatching to adult was 43 days. Adult life under laboratory conditions extended for 31 days.

Eggs obtained from first-generation laboratory-reared malformed adults of Melanoplus bivittatus were hatched and the grasshoppers reared in the laboratory. All of these second-generation grasshoppers reaching the adult stage were perfectly formed, lending additional support to the theory that the malformations are not genetic. In a subsequent experiment, using eggs from the same malformed parents, numerous individuals died shortly after becoming adults. Specimens sent to the Insect Pathology Laboratory have been determined to be infected with a fungus resembling Aspergillus flevus LK ex. Fr. In this group of grasshoppers an occasional malformed adult was observed. Since approximately 100% of the insects were diseased, with less than 1.0% being malformed, it appears that disease is not the cause of the malformations. Physical factors of the rearing procedure are still considered responsible.

2. Alfalfa Insects. Feeding tests with the alfalfa weevil were conducted at Beltsville, Md., using 47 different plants. Both larvae and adults fed on nearly all the true clovers, Trifolium spp., and on yellow and white sweetclover, Melilotus. Plants fed upon by adults but not by larvae were soybeans, mustard, rape, and black locust. Adults refused to feed on or lay eggs in one hop clover, Trifolium patens, when confined on it, but readily laid eggs in it when alfalfa or sweetclover was also available for food. This indicated the presence of a feeding deterrent and absence of an egg-laying deterrent in this clover. The presence of feeding and egg-laying stimulants has been demonstrated in ether and water extracts of fresh alfalfa. Partial success has been achieved in the formulation of an artificial diet by incorporating leaf extracts in an agar base.

Continuous laboratory rearing of weevils has been accomplished at Beltsville, Md., by maintaining larvae under short day lengths of 8 hours light. Under these conditions the diapause inherent in field populations is either lost or selected out in 2 generations. After the fourth generation, the time from adult emergence to first egg-laying stabilized at 3 to 4 weeks. This makes possible the production of six generations per year in the laboratory as compared to one in the field.

Controlled matings at Beltsville, Md., between eastern weevils and weevils from four western locations substantiated results obtained in 1961. Western males crossed with eastern females produced infertile

eggs, while reciprocal crosses produced fertile eggs. The sex ratio of the "EW" hybrids was 8.5 females to one male as compared to the normal ratio of 1 to 1. Back-crosses are in progress to determine more clearly the degree of sexual isolation existing between the two populations.

Egg laying forms (sexuales) of the spotted alfalfa aphid were collected in 26 additional Nebraska counties in the fall of 1962 making a total of 49 counties in which these forms have been found. Sexuales were also reported from one county in Kansas and several additional counties in South Dakota. Egg hatching was observed during 1961, 1962, and 1963 and first instar nymphs were detected in mid-April. Populations began to increase during May but always declined before reaching economic levels. This decline appeared due to predator activity.

At Mesa, Ariz., damage to alfalfa seedlings by the leafhopper, Aceratagallia curvata, was studied using populations per plant ranging from 2 to 14 males, females, and sexes combined. Seedling mortality was greatest during the first 5 days of testing. Mortality caused by insect feeding decreased arithmetically from males, to females to sexes combined. Longevity of seedlings, infested with 2 to 14 leafhoppers per plant, ranged from 17.5 to 1.5 days, respectively.

3. Clover Insects. In 1962, at Lincoln, Nebr., early spring studies of the sweetclover weevil revealed that contrary to the previous year's findings, overwintered adults were most abundant at night. The second generation of weevils emerging in mid-summer displayed a strictly nocturnal habit. October populations were nocturnal for the most part but many weevils were also found during the day. Preliminary tests in the laboratory indicated that the weevil may be strongly nocturnal except when in a state of partial starvation. Under this condition the weevil is attracted to light in search of food.

Host range studies with the sweetclover aphid in the greenhouse at Lincoln, Nebr., revealed that all of the species of Melilotus available served to varying degrees as hosts. In the closely related plant genus, Trigonella, 8 of the 20 species tested were rated as non-hosts of the aphid. As far as is known the aphid does not have host species outside these two plant genera.

4. Grass Insects. Investigations were conducted in the sandhills area of Nebraska on a white grub, Phyllophaga anxia, that damages grasses in sub-irrigated hay meadows. The insect appears to have a 3-year cycle. In the spring of 1962, the majority of grubs were in the 3rd instar. Pupation began in late July and in mid-August beetles were found in the soil where they overwintered. Grubs burrow deeper into the soil in the fall and return to near the surface to feed in the spring. A definite relationship between grub populations

and soil moisture was observed. No grubs were found in the dry upland areas and populations were quite low in areas of excessively wet soil. Beetle flight, determined by using Japanese beetle traps, extended from May 25 to June 24. More beetles were caught in a wet meadow than in an upland area.

At Tifton, Ga., a black light trap caught 14 times more males than females of a bermudagrass spittlebug, Prosapia bicincta. Periodic sweeping of an area near the trap showed the population to be approximately 61% females, indicating that the trap had little effect on the sex ratio. In the spring the first newly emerged spittlebug nymph was found 21 days after soil temperature had reached and remained above 65° F. In the laboratory eggs required 17-21 days to complete their development when held in contact with moisture at 70° F. This spittlebug has been reported on a large variety of plants including such economic species as pangolagrass, St. Augustinegrass, coastal bermudagrass, and millet.

The bermudagrass mite, Aceria neocynodonis, was infesting Arizona common bermudagrass breeding plots at Tifton, Ga., in October 1962. A survey of other varieties and species of grass revealed no other infestations. In November adults, nymphs, and eggs were present beneath leaf sheaths. During December temperatures dropped to a low of 6° F. and no mites have been found since that time.

5. White-fringed Beetles. From 1958 through 1962 at Florala, Ala., a study was conducted to determine the difference in survival of white-fringed beetle larvae, Graphognathus leucoloma fecundus, in field plots planted to a winter crop as compared to the survival in plots without a winter crop, the rate of growth of larvae under these conditions, and the effect of population density on survival and rate of growth. All plots were planted to cowpeas each summer, and ryegrass was used as the winter crop. Each year in August or September the plots were infested with egg masses at the rate of 213, 426, 639, and 1,279 eggs per square foot. The larval populations, larval size, and depth of the larvae in the soil were determined in early February and early April each year. With each greater rate of infestation there was an increase in the larval population. At each examination and each rate of infestation the survival was greater in the plots provided with winter food plants. The winter food plants caused an average increase in survival for all rates of infestation of 81.3% in the February examinations and of 91.8% in the April examinations. An increase in larval size resulted from the supply of winter food, while higher rates of infestation caused a decrease in size. Winter food plants and the rate of infestation did not cause any appreciable difference in vertical distribution of the larvae in the soil.

B. Insecticidal and Cultural Control

1. Grasshoppers. During the winter of 1962-63, 50 new compounds were screened at Bozeman, Mont., using Melanoplus bivittatus and M. sanguinipes. The following 9 compounds were equal in toxicity to the aldrin standard: Hercules 7845C; Mobil MC-A-600; and Stauffer B-9340, B-9714, B-10204, B-10205, B-10341, R-5722, and N-4539. Seven of those tested equaled the aldrin standard at twice the dosage. These were: Monsanto CP 19203; and Stauffer B-9713, B-10175, R-5977, R-5723, R-5725, and N-2793.

In 1962, 5 compounds were field tested on 2-1/2-acre plots using ground equipment. American Cyanamid 43064 at 6 ounces per acre was superior to the aldrin standard. Bayer 39007 at 6 ounces per acre compared favorably with the standard, but General Chemicals 4072, at 8 ounces, Dibron 8E at 6 ounces, and Bayer 41831 at 8 ounces per acre were inferior.

Spray volumes of 1 pint to 1 quart per acre were applied to 40-acre rangeland plots by means of a Piper Pawnee airplane flying 100-foot swaths for grasshopper control. Comparisons were made between the Micronair Rotary Atomizer, Model AV-2000, producing droplets with an average diameter in the range of 84 microns and a standard boom arrangement producing droplets in the range of 150-200 microns. With the boom arrangement, 3/4 ounce of dieldrin in diesel fuel per acre gave kills of 79 to 99% at the 1-pint volume and 93 to 96% at 1 quart. A standard application of 3/4 ounce dieldrin in 1 gallon of diesel oil per acre gave kills of 94 to 97%. In the same series of tests the Micronair unit gave kills of 65 to 98% at the 1-pint volume and 80 to 98% at 1 quart.

In tests in eastern Montana with small aircraft (Piper Pawnee) on 40-acre range plots in 1962, Bayer 25141 in diesel oil at 2 ounces per acre gave kills equal to the aldrin standard. General Chemical GC-3707 applied as an emulsion gave kills equal to the standard at a dosage rate of 4 ounces per acre. Malathion at 8 ounces in emulsion was inferior to the standard. Dimethoate emulsion at 1 ounce per acre with additives of plyac, molasses, and ethylene glycol was inferior to the standard. However, the addition of plyac at 2 ounces per gallon increased the kill approximately 10%. Molasses at 1 quart per gallon of spray increased the kill by 6%, while ethylene glycol had no apparent effect.

In tests with Twin-Beech aircraft on 320-acre plots in eastern Montana, Bidrin, General Chemical GC-3707, and dimethoate, all at 2 ounces per acre, gave kills inferior to the aldrin standard. In the case of GC-3707 and dimethoate the kill was approximately 10% less than similar dosages applied by small aircraft. Since the flight height of the Twin Beech was 100 feet compared with 40 feet for the

Pawnee, it was theorized that the lower kill from the large aircraft might be due to greater loss through evaporation of the water emulsions.

In May 1963 in California, malathion was applied with a Stearman aircraft on 160-acre plots of rangeland. A new formulation consisting of 95% malathion per gallon was applied in panasol, an aromatic naphtha solvent, at 12 ounces in 1 quart per acre. An emulsion concentrate containing 8 pounds of malathion per gallon was applied at 12 ounces in 1 quart and one gallon per acre. Both formulations gave satisfactory kills.

2. Alfalfa Insects. At Beltsville, Md., applications of Geigy 30494 and Imidan, both at 1 and 2 pounds per acre on October 11 or November 13 failed to give satisfactory control of alfalfa weevil larvae the following spring. Heptachlor at 1 pound and Telodrin at .75 pound per acre gave good control. The addition of the adjuvant, Cellosize QP 4400, to 5 phosphate insecticides and methoxychlor decreased control as compared to the materials applied alone. However, EPN and methoxychlor applied as sprays at 2 and 3 pounds per acre, respectively, gave 88 and 82% control compared to 99% for heptachlor at 1 pound.

On November 14, 1962, applications of Telodrin at 1/4 to 1/2 pound per acre and heptachlor at 1 pound gave 96 to 100% control of alfalfa weevil larvae the following spring. Fall applications of methoxychlor gave fair control but applications of Guthion, EPN, and selica-gel were not effective.

In the spring of 1962 applications of Guthion and dimethoate with and without the adjuvants LS 0531, Sterox AA, Igepal CO 630, and Sun X223-5 showed no significant differences in alfalfa weevil control between Guthion and Guthion combinations, but the addition of Igepal CO 630 to dimethoate increased control significantly over dimethoate alone. Guthion alone, dimethoate plus Igepal, and heptachlor at rates of 0.5, 0.25, and 0.25 pound per acre, respectively, gave 80 to 85% control 20-days after application. The three promising insecticides Imidan, Geigy 30494, and Telodrin at respective rates of 1.0, 1.0, and 0.25 pound per acre gave 97 - 99% larval control 10 days after application. At 20 days after application, the percentages of control were 72, 84, and 94, respectively. Good control of the pea aphid was obtained with Geigy 30494 up to 10 days, and good control of the meadow spittlebug was obtained with Imidan and Telodrin up to 20 days. Of 10 experimental phosphate insecticides applied as sprays, 9 gave alfalfa weevil control equal to heptachlor at 10 days after application and 3 were only slightly less effective than heptachlor at 20 days.

Applications in the spring of 1963 were made to test materials previously screened in the laboratory for control of the alfalfa weevil. Experimental materials at 1 pound per acre that gave 95% or better control after 14 days were: GC 3707, GC 4072; Imidan; Bayer 25141; Amer. Cyan. 43064, 47470, 47031; CP 19203, 40296; and Hercules 6286. Shell 7438 at 1 pound gave 83% control at 14 days. Applications of Bacillus thuringiensis and the nematode DD 136 were not effective.

According to laboratory tests at Beltsville, Md., the alfalfa weevil has developed a high degree of resistance to heptachlor at several eastern and western locations. Collections from Logan, Utah, Lovelock and Fallon, Nev., Bozeman, Mont., Shell, Wyom., Clarksville and Westminster, Md., and Harrisonburg, Va., were resistant. No resistance was indicated in collections from Franklin, Tenn., Salisbury, N. C., Beltsville, Md., Moorestown, N. J., University Park, Pa., and Mitchell, Nebr.

3. Clover Insects. Results of 1962 tests in Nebraska again showed that plowing before spring regrowth had reached the bloom stage resulted in average reductions of 99% in the developing sweetclover weevil populations.

At Forest Grove, Oreg., fall and early winter applications of heptachlor granules at 12 to 16 ounces per acre gave 93 to 99% control of the clover root curculio. October applications of aldrin granules at 12 ounces per acre and dust mixture containing 32 ounces of methoxychlor and 13 ounces of malathion gave less than 30% control. The heptachlor granules also gave from 66-95% control of the lesser clover leaf weevil.

4. Grass Insects. At Tifton, Ga., phorate granules applied at 2 pounds per acre in June gave 100% control of the spittlebug, Prosapia bicincta, nymphs in 2 weeks and controlled adults over a 30-day period. Treated plots yielded more and better quality grass than untreated plots. Granular applications of carbophenothion, endosulfan, and Sevin and spray applications of Di-syston and dimethoate did not give satisfactory control.

Several insecticides were tested at Tifton for the control of the fall armyworm on bermudagrass and pearl millet. Diazinon and Guthion gave fairly good control at one pound per acre; Sevin at 2 pounds per acre gave about 80% control. Zectran gave good control at 4 ounces per acre and spray formulations gave better control than granules. Endosulfan was less effective than other insecticides tested.

Samples of grass from plots treated with Imidan at 4, 8, and 16 ounces per acre, were fed to 3-day old fall armyworms in the laboratory at Tifton, Ga. One day after application samples taken from the 16-ounce level produced 100%, from the 8-ounce level 49% and from the 4-ounce level 34% mortality in 24 hours.

5. White-fringed Beetles. At Florala, Ala., pot tests exposed to outdoor weather and temperatures were conducted with Sevin, Hercules 5727, American Cyanamid 24055, diazinon, American Cyanamid 18133, Telodrin, and Bayer 29852, to determine their effectiveness as soil insecticides for the control of white-fringed beetles. These materials were used at rates of 0.5, 1, 2.5, 5, and 10 pounds in 403.3 cubic yards of soil, the upper 3 inches of an acre. Telodrin was highly effective against newly hatched white-fringed beetle larvae, all dosages giving complete mortality. The other materials were not effective at the highest dosage used.

In outdoor soil chambers, aldrin, dieldrin, and heptachlor were mixed into the upper 3 inches of soil in July 1957 at rates of 0.5, 1, 3, and 5 pounds per acre. These chambers have been infested each year with newly hatched white-fringed beetle larvae. In 1961-62, the 0.5-pound dosage of aldrin gave 97% and the 1-pound dosage of heptachlor gave 98% control, while all other dosages gave complete mortality.

Granular application of dieldrin and heptachlor at 3 and 5 pounds per acre and emulsion at 5 pounds of the insecticides per acre on the soil surface around established azalea and camellia plants at Florala failed to eliminate all white-fringed beetle larvae. However, dieldrin has given better control than heptachlor.

C. Insecticide Residue Determinations

1. Endosulfan Residues. Coastal bermudagrass at Tifton, Ga., treated with endosulfan emulsion at 0.25, 0.50, and 1.00 pound per acre contained 0.98, 1.95, and 7.07 p.p.m. residues, respectively, when cut 7 days later. On the 78th day after ensiling, the residues in the silage were 0.37, 0.56, and 2.45 p.p.m. for the 0.25, 0.50, and 1.00 pound treatments. Analysis of milk from dairy cows fed the silage, with samples taken at intervals of 1, 3, 6, 13, 20, and 28 days of feeding, showed no detectable residues.

Endosulfan as an emulsion spray was applied at 1.8 pounds per acre to three 2-acre pastures of coastal bermudagrass. An untreated pasture served as a control. Samples of grass taken at intervals after treatment showed up to 0.36 p.p.m. endosulfan 71 days after treatment. Three beef animals were placed on one of the treated pastures at intervals of 1, 7, and 13 days after treatment and grazed for 31, 35, and 36 days, respectively. Animals were grazed for 31 days on the control pasture. Residues on the grass during the grazing

periods ranged from 32.80 to 1.30 p.p.m., 5.76 to 0.75 p.p.m., and 3.50 to 0.77, for the 1, 7, and 13-day waiting periods. Chemical analysis of fat samples obtained by biopsy from the exposed and control animals indicated that no endosulfan was present.

Endosulfan was incorporated into rye silage at 10 and 100 p.p.m. and placed in gallon jars. Analysis indicated that residues remaining after 11 weeks of storage were approximately 40% of the initial amounts added to the silage.

2. Phorate Residues. In the greenhouse at Tifton, Ga., phorate residues in foliage toxic to Drosophila melanogaster adults were detected significantly sooner after application to soil surface than from a water emulsion of the same insecticide injected into the root zone. Residues resulting from granular heptachlor, surface applied, were not detected significantly sooner than those of phorate emulsions injected into the root zone.

3. Heptachlor Residues. At Forest Grove, Oreg., red clover was treated with 2-1/2% granular heptachlor at the rates of 1/4 and 1 pound of heptachlor per acre. Samples taken 4 months after treatment and analyzed at Yakima, Wash., contained measurable amounts of heptachlor but no measurable amounts of heptachlor epoxide. Red clover treated with 1 pound of heptachlor as an emulsifiable concentrate and harvested 6 months later did not contain measurable amounts of heptachlor or heptachlor epoxide.

D. Biological Control

1. Grasshoppers. At Bozeman, Mont., laboratory and field studies were initiated to ascertain the effect of the protozoan disease, Nosema locustae, on grasshoppers. During the summer of 1962 the organism was found in grasshoppers collected in Minnesota, eastern Montana, and southern Idaho. Infections of this organism have occurred in at least 11 species of grasshoppers. The disease reduces rate of development, increases death rate and reduces weight of adults.

In Montana and Idaho, species of Tachinidae, Sarcophagidae, and Nemestrinidae were found parasitizing grasshoppers. Mermithed worms were common during the early summer. A fungus resembling Aspergillus flavus produced high mortality rates in Camnula pellucida collected near Fernwood, Idaho, and Lamedeer, Mont. The same fungus produced high mortality rates in some laboratory-reared Melanoplus bivittatus. Efforts to isolate viruses from grasshoppers have been unsuccessful.

The life history of the parasitic grasshopper mite, Eutrombidium sp., was studied at Columbia, Mo. The pre-oviposition period averaged 13.8 days. The average time from egg laying to the deutovum stage was 8.2 days, and final hatching occurred about 10.5 days later. The larvae searched out and attached to available grasshoppers where they remained for an average of 22.2 days. After engorgement the mites underwent a pre-nymphal, quiescent period which averaged 21.3 days. The nymphal period was about 32 days during which time the mites fed readily. Preimaginal pupation required about 17 days whereupon the adult emerged. Females produced an average of 2.7 egg masses.

Erythraeid mites identified as Leptus sp. were recovered from Melanoplus differentialis and M. femur-rubrum which were sent to Columbia from Wooster, Ohio. Larvae attached to nearly all parts of the grasshoppers where membranous areas were present, especially at the base of the hind wings. Detached engorged larvae were mobile, six-legged, hairy creatures, red-orange in color and 1 to 1.5 mm. in length. The life cycle required about 127 days. Both the nymphs and adults fed readily on grasshopper eggs.

2. Spotted Alfalfa Aphid. Aphelinus semiflavus and Praon palitans, imported parasites of the aphid, were not observed in Arizona in 1962. However, the latter species was observed in one field in 1963. The known State range of Trioxys utilis, a third imported parasite of the aphid widely established in central and southern Arizona by 1961, was not extended according to surveys made in 1962. In 1962 parasitization by T. utilis was observed in only two fields and averaged less than 1% but this parasite was more widely distributed and abundant in 1963.

Observations on the spotted alfalfa aphid and its natural enemies were continued bi-weekly in 1962 in 4 untreated alfalfa fields near Mesa, Ariz. Compared with 1961 there were moderate to large increases in such predators as beetles, nabids, geocorids, syrphid fly larvae, and lacewing fly larvae, a slight increase in Orius spp., and a slight decrease in Collops vittatus.

3. Alfalfa Weevil. The alfalfa weevil has continued to spread in the Eastern States and now occurs throughout the Eastern alfalfa growing areas from Mississippi and Arkansas, northeast through Ohio, to southern New Hampshire and Vermont. Parasites, primarily Bathyplectes curculionis, were released on 4 lines extending northwest from origins in Georgia, North Carolina, New Jersey, and Massachusetts. Of 24 releases made in 1961 and 1962, the parasite has been recovered from 23; the 24th site was not sampled. Five additional releases were made in 1963 in newly infested areas of Tennessee, Ohio, and New York.

Several other introduced parasites have been released. Tetrastichus incertus released in 1961 in 9 sites in 5 States and at 2 sites in 1962 was recovered in Chester County, Pa., in 1962. Dibrachoides druso released at 4 sites in 3 States in 1961 and at 2 sites in 1962 has not been recovered. Peridesmia discus released at 1 site in 1961 has not been recovered. A small release of Microctonus aethiops was made in 1963 at Raleigh, N. C. This parasite has become established in New Jersey where it was released several years ago. Bathyplectes anura was released and recovered the same season at one site in Pennsylvania.

A native egg parasite, Pattasson luna, was reared from alfalfa weevil eggs collected at Beltsville, Md., in April and May 1962. Under laboratory conditions adult parasites were able to parasitize only newly laid undeveloped host eggs. Parasite development from oviposition to adult emergence was completed in 10 days.

A preliminary field cage test at Beltsville, Md., was conducted in 1962 to determine the relative numbers of Bathyplectes needed to control the weevil in a single season. Parasites were introduced at the rates of 5 pairs, 2 pairs, and 1 pair per 500 host larvae. There were obvious differences among treatments in amount of leaf damage and number of weevils maturing but complete control was not achieved. The host population in terms of adults produced was reduced 60% by 5 pairs of parasites and the rate of parasitism was 14.3% based on beginning larval populations and number of parasite cocoons recovered.

4. Grass Insects. Preliminary field and laboratory tests at Lincoln, Nebr., indicated that grubs of Phyllophaga anxia from the Nebraska sandhills are susceptible to milky disease. Spore powder was applied to field plots on May 22, 1962, and on November 7, diseased third instar grubs were found. One diseased grub was approximately 10 feet from where the spore powder was applied. In the laboratory, third instar grubs became milky when placed in infected soil with suitable food. Healthy grubs were readily infected by injecting with blood from diseased grubs. Grubs of this species were attacked in the field by a naturally occurring fungus, Metarrhizium anisoplia, and a naturally occurring insect parasite, Microphthalma michiganensis. The incidence of both of these control agents was extremely low. A mite, Caloglyphus sp., was found abundantly in association with the grubs but was determined to be a scavenger.

5. Armyworms and Cutworms. Due to unusual cold and prolonged drouth conditions the armyworm and fall armyworm populations were very low in Louisiana. A few larvae of possible alternate hosts of armyworm parasites were collected. One of these yielded an armyworm parasite, apparently Meteorus autographae, and another two specimens believed

to be Apanteles marginiventris which attacks the fall armyworm.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. White-fringed Beetles. At Florala, Ala., studies of the attractiveness of certain plants to white-fringed beetle adults were continued in 1962. Field-collected adults were released in the center of an outdoor cage, 24 by 24 feet, where they had a free choice of movement. Peanut, sicklepod, and cocklebur plants covered with double screen wire cages to prevent beetles from feeding on the foliage, and cages without plants, were placed near the outer edge of the large cage. The adults found on the small cages were removed 3 times each day. Slightly more beetles were found on the cages containing plants than on the empty cages. Cages containing plants infested with beetles were more attractive than cages containing plants without beetles.

In other tests one hill of peanuts was planted in the center of 80 hills of corn in a cage 30 by 30 feet in size. Field-collected adults were released at the 4 corners of the area, or 15.5 feet from the peanut plant. The beetles found at the peanut plants were removed three times each day. From July 17 to August 20, 3,100 adults were released in 2 test areas and only 10.1% were recovered at the peanut plants. Apparently the adult does not possess the ability to detect a favored host plant by smell or sight.

F. Evaluation of Equipment for Insect Detection and Control

1. White-fringed Beetles. Tests were begun at Florala, Ala., in 1960 to study the relative effectiveness of strip and broadcast applications of certain insecticides against white-fringed beetles on noncultivated land. A special applicator was used that applied granular formulations of insecticides in narrow bands 12 inches apart on the soil surface in such a manner that the insecticide would not come in contact with the plant foliage. The plots were treated in October 1960 and infested with egg masses in 1960 and 1961. Larval populations were determined in April 1961 and again in April 1962. Aldrin, chlordane, dieldrin, heptachlor, and Sevin were used at 2 or 3 rates. Sevin was not effective as a surface treatment. The broadcast applications gave better control than the strip applications during the first year following treatment, but during the second year both types of treatment were equally effective. This machine disturbed the surface of the soil thereby enabling newly hatched larvae to penetrate the soil more readily. This factor caused a greater survival in all plots treated with the machine than in the plots receiving broadcast applications in the first year following treatment but not in the second year. In plots which received no insecticide the soil disturbance from the machine caused a 91% increase in survival over that which occurred in untreated

nondisturbed plots in 1961, and a 60% increase in 1962. The smaller dosages of aldrin, chlordane, dieldrin, and heptachlor were less effective than the larger dosages.

G. Varietal Evaluation for Insect Resistance

1. Spotted Alfalfa Aphid. Sonora, a new non-dormant spotted alfalfa aphid resistant variety developed in the cooperative alfalfa improvement program in Arizona, California, and Nevada, was released in 1962. The variety is adapted to the lower desert valley areas of Arizona, California, and southern Nevada and presumably to areas in northern Mexico which have similar growing conditions.

At Mesa, Ariz., 18 alfalfa plants, progenies from four clones of Chilean 21-5 selected for resistance to the spotted alfalfa aphid, were caged tested for antibiosis and 14 rated highly resistant. This indicates that it may be possible to develop a resistant variety from Chilean 21-5.

Studies on the spotted alfalfa aphid at Mesa, Ariz., showed that mortality of infested seedlings of resistant and susceptible alfalfa varieties was the same up to 15 days following germination. This suggested that certain mechanisms of resistance were not operating during this critical period, and insecticidal treatment of resistant varieties may be needed in the seedling stage if populations of aphids are high.

At Tucson, Ariz., seedlings of 13 synthetic combinations, constituted by members of the Southwest Alfalfa Group, were evaluated for resistance to biotypes ENT A and ENT B of the spotted alfalfa aphid. Resistant Moapa and Sonora were used as checks, and 3 commercial varieties were also included. Outstanding synthetics were SW-12 and SW-13, both California combinations. SW-12 was rated best in ability to make growth following infestation, and SW-13 gave top performance in plant survival (78%). Also excellent in plant survival was SW-17 (74%), a two-clone Arizona combination, and SW-21 (66%), a California coastal and high desert combination.

At Lincoln, Nebr., seedling progenies of aphid resistant and aphid susceptible clones were mass infested with parthenogenetic forms of the sexuales-producing strain of the spotted alfalfa aphid. Plants resistant to the solely-parthenogenetic strain of the aphid were also resistant to the strain which has the ability to produce sexuales. Aphids from neither strain lived much longer than 3 days when confined to resistant plants, indicating that apparently there are no basic differences between the two strains in regard to host plant resistance.

2. Lygus Bugs. At Mesa, Ariz., the screening of 2,000 alfalfa plants representing several varieties and experimentals resulted in selection of 36 with moderate promise for resistance to lygus bugs. Most of these plants had some damage, and none showed the marked reaction desired for breeding resistance into new varieties.

3. Alfalfa Seed Chalcid. Fifty-four varieties of alfalfa at Yuma and 48 at Mesa, Ariz., were evaluated for resistance to the alfalfa seed chalcid. Among entries having the lowest mean infestation at Yuma were A-224, Orestan, Chilean 21-5, and New Mexico 11-1, and at Mesa, Zia, Williamsburg, Rambler, and Talent. Lahontan, which showed promise in earlier tests, ranked 8 and 13 in the Yuma and Mesa studies, respectively. Among 5 clones which comprise the variety Lahontan, clone C-89 had the lowest chalcid population in two separate tests. Apparently this clone contributes most to the slight resistance in Lahontan to the alfalfa seed chalcid.

Over 2,000 individual plants from 18 different sources were screened for resistance to the chalcid in tests at Mesa. Nearly 300 plants were selected from this group on the basis of having less than 30 chalcids per raceme. Most of the promising material was selected from the two-clone combinations in which M-56-11, an important source of chalcid resistance, was crossed with three high-yielding selections out of African.

4. Pea Aphid. At Lincoln, Nebr., research is continuing in the development of combined pea aphid and spotted alfalfa aphid resistance. Nebraska synthetic 27, whose parents had been selected for resistance to both aphids in greenhouse tests, showed a high level of pea aphid resistance under a heavy aphid infestation in a field cage. In general there was close agreement between greenhouse and field cage results with all plants tested.

At Poznan, Poland, (P. L. 480 project E21-ENT-9) two preliminary tests showed some antibiosis of lupine plants to the pea aphid. In the first test Gorki (yellow), Wielkopolski (blue) and Przebedowski (white) revealed some resistance as measured by extremely low aphid reproduction. The second test with 12 varieties confirmed these results and revealed similar resistance in varieties Osbornicki (yellow) and Przebedowski Wczesny (white).

5. Potato Leafhopper. Counts were made at Lincoln, Nebr., of adult and nymphal populations of the potato leafhopper on established varieties, plant introductions, and experimental synthetics of alfalfa at peak leafhopper infestation during mid-July. No correlation was found between leafhopper populations and a system of visual rating based on the degree of plant yellowing. There is apparently no difference in attractiveness to the potato leafhopper among these alfalfas, and differences in degree of plant yellowing are probably due to tolerance.

At University Park, Pa., 15 selected alfalfa clones were tested in the greenhouse, laboratory, and control chamber to determine percent egg viability, time for nymphal development, and plant preference of potato leafhopper nymphs. There were significant differences for length of nymphal development and nymphal feeding preference. Males developed approximately one day sooner than females. These same clones were replicated in a spaced nursery and half of them were sprayed. A plant color rating and nymphal count on the unsprayed clones showed a significant correlation. This may not be a true relationship, however, because adults are attracted to yellow, and therefore to yellowing alfalfa. A comparison of the dry weights of injured and sprayed top growth showed that color and stunting are not always related. In order to measure antibiosis, unaffected by yellowing, potted clones from the greenhouse were exposed briefly to egg laying in the field, and were then returned and held 19 days while nymphs hatched and developed. Results showed significant population differences among the clones that were unrelated to either color or dwarfing. Yellowing, dwarfing, and antibiosis were unrelated but important factors that should be evaluated in selecting plant material for resistance to the potato leafhopper.

6. Alfalfa Weevil. At Beltsville, Md., four alfalfa nurseries containing 151 entries were rated for larval damage in 1961 and 1962. Entries with the lowest damage ratings for the 2-year period were species of Medicago falcata, several entries of the variety Narragansett, and plant introduction numbers 151671, 212798, 213394, 234482, and 235821. Only the variety Narragansett is agronomically suitable for hay production. On the basis of correlations between damage ratings and measurements of plant characteristics there was a tendency for profuse stem branching, slow recovery after cutting, and yellow or variegated flowers to be associated with low damage ratings. These characteristics are typical of M. falcata.

No significant differences were found among 106 alfalfa entries in laboratory and greenhouse tests designed to measure larval damage on uncaged potted plants, larval survival and weight on cut caged stems, or larval survival on stems caged over potted plants. In these tests initial infestations were obtained by using known numbers of eggs or newly hatched larvae. A highly significant correlation of 0.3722 was found, however, between the number of eggs laid per inch of stem in the laboratory and larval field damage ratings. This egg laying preference test utilized cut stems in water in a common cage containing mature weevils. Additional egg laying preference tests were made with 24 entries selected to represent the range of differences observed in the entire group, and in addition, stems were rated for adult feeding damage and measured for stem diameter. Correlations between average performance ratings or measurements for these 24 entries gave highly significant values of 0.7613 between field larval damage ratings and egg laying preference in the laboratory, 0.6111 between field damage

and stem diameter, 0.5980 between stem diameter and egg laying, and 0.5694 between stem diameter and adult feeding. Thus either or both stem diameter and feeding preference appear to be closely associated with egg laying and resulting larval damage.

7. Sweetclover Aphid. At Lincoln, Nebr., 98 accessions of plant introductions of sweetclover, provided by the Crops Research Division, were screened for sweetclover aphid resistance. None of these accessions were uniformly resistant but a number of them contained one or more resistant plants. The lines from which resistant plants were selected came from many different areas of the world. The accession (PI-178985) producing the greatest number of resistant plants was of Turkish origin. Heritability of resistance in the majority of the selections was confirmed by testing selfed-progeny.

8. Sweetclover Weevil. Sweetclover weevil larval populations were determined in a field nursery containing 4 common varieties, Spanish, Denta, Madrid and Goldtop, and one experimental, N-13. The mean number of larvae per square foot of soil ranged from 28.6 for Spanish to 58.7 for Denta but these differences were not statistically different.

Since practical levels of resistance to the sweetclover weevil have not been uncovered in the screening of varieties and lines, screening tests were conducted at Lincoln, Nebr., on all of the available species of the sweetclover genus, Melilotus, and a closely related genus, Trigonella. One species of Melilotus was nearly immune to feeding by the adult weevil. It is hoped that this species can be crossed with the common sweetclover species.

H. Insect Vectors of Diseases

1. Vectors of Red Clover Root Rots. At University Park, Pa., studies were made to determine whether the control of root weevils and root rots would increase the longevity of red clover stands. Plots were sprayed periodically with insecticides and fungicides singly and in combination during the seedling, first, and second year. At the beginning of the third harvest-year (or fourth year) the percent of ground cover for check plots averaged 1; fungicide plots 1; insecticide plots 45; and combined fungicide-insecticide plots 45.

Results of a greenhouse experiment made at University Park, Pa., showed for the first time that larvae of Calomycterus setarius fed on small rootlets of red clover, and when full-grown, gouged the top and lateral roots. The crown and root weights of weevil-damaged plants were less than those in the controls. Of the 4 treatments--control; soil infested with C. setarius; with Fusarium spp.; and with both C. setarius and Fusarium spp.--most root rot developed on plants given the last treatment, with small differences among those in the other treatments.

2. Tumors on Alfalfa. At University Park, Pa., an alfalfa plant with tumors was found during tests for resistance to potato leafhoppers. The tumors occurred at the feeding sites on stems, petioles, and leaves. The epidermis usually ruptured within 42 to 48 hours after feeding by nymphs or adults and the growth development terminated within 5 days. Tumors could be produced artificially by pricking leafhopper body juices into the plant tissues with a needle. Heat and formalin used to destroy virus did not affect tumor growth.

3. Insect Vectors of Lupine Diseases. Continued studies at Tifton, Ga., of aphid abundance on yellow lupine after treatments with granular phorate and emulsion sprays of dimethoate, at 2 pounds of the insecticide per acre indicated (1) that the insecticides persisted in the plants, as determined by comparative biological assays utilizing Drosophila melanogaster adults; (2) that aphid populations were greatly reduced after both treatments; and (3) that the reduction of aphids was associated with a reduction in bean yellow mosaic virus in the plants.

4. Vectors of Lupine Viruses. At Poznan, Poland, research under P. L. 480 project, E21-ENT-9 in which the green peach, bean, and pea aphid were used as vectors, double transmission of bean yellow mosaic virus and cucumber mosaic virus from infected to healthy lupine plants was successful only with the green peach aphid. The other aphid species transmitted each of the viruses singly but never both simultaneously. The green peach aphid was the most efficient vector, followed by the pea aphid and the bean aphid.

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PRODUCTION, HARVESTING AND FARM STORAGE
STRUCTURES, EQUIPMENT AND METHODS
Agricultural Engineering Research Division, ARS

Problem. Better methods, techniques, equipment and structures for use on the farm for producing, harvesting, storing, and the initial preparation of grain and forage crops for market are needed to increase efficiency in the use of labor and equipment, preserve quality and prevent spoilage and damage from mechanical handling and insects.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers, statisticians, physicists, and architects engaged in both basic and applied research in this area. The total effort involves 22.3 professional man-years. Of this number, 2.7 are devoted to equipment for establishment of forages, 2.8 to insect control in grain, 1.3 to weed control in corn and soybeans, 1.1 to energy radiation equipment for seed treating, 3.0 to harvesting equipment for forage and seed, 5.4 to drying grain and forage, 1.0 to pelleting forage, 2.5 to seed cleaning and 2.5 to structures for grain and forage. Work is carried on at Beltsville, Md.; Athens, Experiment, and Tifton, Ga.; Ames, Iowa; Lincoln, Nebraska; Corvallis, Oregon; Clemson, S. C.; and Bushland, Texas; in cooperation with State experiment stations.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Equipment for Establishment of Forages.

1. Twenty-one experiments on the establishment and production of pastures and haylands were put in cooperatively with State and Federal research units. Thirteen experiments were handled out of the Beltsville Station, three by the Southeastern Station, and five by the Southwestern Station. Some typical responses to the various studies are: In the rangeland of the Southwest excellent stands of three desirable forage species (switchgrass, sprangle top, and sideoats) were established in poor rangeland at one location with a special range mulcher-seeder machine in 1962. Seeding at another location was not successful. Considerable study and experimentation will be necessary to provide dependable methods and equipment, but this study shows promise of developing suitable equipment and practices for this problem. The successful establishment of a desirable legume in an established grass sod was repeated again in studies with the University of Maryland (trefoil-bluegrass). The use of a curved disk coulter displaced enough sod and gave suitable seedbed preparation for a grassland drill seed-fertilizer opener to firmly establish this legume. (It is difficult to get a good stand with this species in the mid-Atlantic area.) Further studies on management are following up this successful method of establishment. In a five-year study of the effect of nitrogen fertilization on forage production of an estab-

lished stand of irrigated legume grass in the Northwest (ladino-orchardgrass - management studies) the greater production showed no profit the first two years. Two hundred pounds of N (\$30) per acre were added - forage market price of \$20/ton dry matter. However, on the third year, over \$7 per acre was received as additional net return over no fertilization, \$16 the fourth year, and \$10 the fifth year.

B. Corn Planting and Fertilizing Equipment.

1. Fertilizer placement studies on corn in Georgia have been terminated after three years of trials. As found previously, the 1962 studies gave further proof that one operation corn growing is highly feasible. More profit can be made as the one operation of planting, fertilizing, and cultivating has the lowest cost of producing high yields of corn. Treatments indicate that fertilizer applied on a 2 X 2 basis (two inches below and two inches to side of seed) in a complete analysis at planting time will give higher yields than split applications of nitrogen. The application of a pre-emergence herbicide (Atrazine) can eliminate the need for cultivations or post-emergence herbicides.

C. Insect Control in Grain.

1. In investigations made in cooperation with the Iowa Station for the control of the European corn borer, the major emphasis of the chemical control program was to screen new insecticides, develop systemic insecticide control, study the effect of particle size and amounts of carriers in granular formulations, and to study the rate of loss of insecticide residue on corn plants. The results of these studies indicated that in addition to the presently recommended insecticides, Telodrin at 0.2 lb./acre, Diazinon at 2 lb./acre, Zectran at 1.5 lb./acre, and Bayer 44646 at 2.0 lb./acre also gave good control of first- and second-brood corn borer larvae. The effectiveness of Sevin was increased by the use of Lovo, a spreader-sticker. American Cyanamid CL47470 and CL47031 showed systemic activity against corn borer larvae. Ground corn cobs were as effective as attapulugus clay granules as carriers for insecticides for borer control. Telodrin residues from granular formulations could be detected 90 days after application and residues from spray applications were less persistent.

Studies were undertaken to determine the effect of commonly used spray mix densities, viscosities, and surface tensions on flow rates with nozzle sizes at different pressures and temperatures. Results show that increases in temperature decrease density, viscosity, and surface tension. These changes in the physical properties of spray mixes were not independent, and although the flow rate was changed with physical property changes additional work will be needed to clearly establish the relationship of spray mix physical properties and flow rate. Experimental sprayers and granule applicators were improved and calibrated for applications of insecticides. The distribution of granules on and around corn plants was given further study.

2. Investigations on new mechanical and/or physical methods for insect control on grain crops have been initiated at the Southern Grain Insects Research Laboratory, Tifton, Georgia. The initial efforts have been devoted primarily to control of the corn earworm. Most of this work is being done in cooperation with other personnel of the Southern Grain Insects Research Laboratory, Tifton, Georgia.

Several methods for controlling the corn earworm have been tried with varying degrees of success: (a) Clipping corn silks off at the tip of the husk at 24 hour intervals did not lessen the infestation of the ears by corn earworms. (b) Orientation of corn ears and foliage was tried in preliminary tests as an aid in applying insecticides. Small scale tests indicated 66 percent of the stalks could be orientated by planting all corn seed in the same direction. (c) Corn silks grow as much as one and one-half inches in 24 hours which continuously expose new silks to insect attack. A gelatinous substance might be used successfully for protecting these new silks from insect attack. Equipment is being developed for applying such a material to corn silks. (d) A method of applying insecticides by brushing or rolling the materials onto areas requiring protection was tried. A wool paint roller was used with little success. However, the use of this roller produced criteria for designing equipment.

3. Field work was begun in 1962 with spraying equipment in Georgia for evaluating factors such as: nozzle types, pressures, gallonage, nozzle incidence angle and number of nozzles per row. No positive conclusions can be drawn from the data obtained because of the limited work completed, however, several facts were indicated: (a) Flat type nozzles are superior to either hollow or solid cone nozzles in spraying for corn earworm control; (b) Two nozzles per row used in these tests is not adequate for effective insect control; (c) Pressures in excess of 100 psi. are seldom justified.

4. Studies were made in Georgia for available methods for evaluating insecticide coverage in sufficient quantities for visual evaluations. A total of 46 dyes were screened as potential indicators of spray coverage. The five following dyes gave best results: Rodomin B, methyl violet, crystal violet, methylene blue, and Rose Bengal. In the field work this year, Rose Bengal dye was used with good results at a one percent solution mixed into the insecticide.

D. Weed Control in Corn and Soybeans.

1. In investigations made in cooperation with the Iowa Station, results from several experiments showed that early spring applications of Atrazine and Simazine on fall plowed, spring plowed, and unplowed ground controlled weeds in corn throughout the season. 2,4-D at 4 lbs. of acid per acre gave good control up to planting time. Although yield and stand differences were not significant at the five percent level, the data showed a slight trend toward improved stands and yields where some tillage was performed prior to planting as compared to no tillage. A rotary tiller that worked

a 12-inch strip two to four inches in front of the planter gave better results than a cultivator sweep in front of the planter or disking in front of the planter.

Continued studies in Iowa on comparisons of liquid and granular herbicide formulations applied at planting time in bands over the row and over the entire area showed that liquids were as effective as granules for most herbicides. Atrazine and Simazine were the exceptions, and the results showed that weed control was more erratic with the granular formulations of these compounds. Strip applications were nearly as effective as broadcast; however, it was always necessary to cultivate at least once where chemicals were applied in strips, and only when the chemicals failed was it necessary to cultivate where overall applications were made.

Studies on mechanical cultivations in Iowa showed that harrowing after planting did little to improve stands, yields, or weed control. However, when the rotary hoe was used with 3 cultivations, harrowing after planting showed a slight improvement in weed control. Although three cultivations gave substantially better weed control than two cultivations, stand and yield data showed that two were as good as three. Two cultivations resulted in yields and stands that were as good as or better than various combinations of rotary hoeing and weeding with two and three cultivations. Shallow cultivations with rotary hoes, dragging hoes, and spring-tined weeders improved the weed control but not enough to materially affect yield.

The effect of varying the percentage formulation and rates of active ingredient of granular herbicides was studied in Iowa. All pre-emergence chemical treatments gave better weed control and higher yields than the untreated check. Ten and 20 percent Atrazine were equally effective. Ten and 20 percent formulations of 2,4-D at the 2 and 4 lb./acre rates were equally effective. The 4 lb./acre rate of 2,4-D did not improve weed control and showed no visual evidence of damage; however, yields were slightly lower than the 2 lb./acre rate. The Atrazine formulations gave better weed control than the other chemicals.

Spherical and regular granular formulations of 10 and 20 percent 2,4-D were applied in Iowa with John Deere, Gandy, and Noble boxes attached to an electrically driven cart that operated on a portable track. Distribution as indicated by photographs of granules caught on a plastic sheet showed little or no difference among machines. The number of granules per square inch varied considerably and there was no indication that patterns of spherical and regular granules were materially different. Spherical granular formulations of the 12/20 mesh size gave better weed control than equal amounts of 12/20 regular granules.

A number of commercially available or experimental herbicides were evaluated in Iowa for pre-emergence weed control in corn and soybeans. Atrazine, Radox and Radox T at recommended rates again resulted in best

weed control in corn. Amiben and Randox gave the best results in soybeans. Directed post-emergence spray applications of Dowpon and 2,4-D combinations resulted in some crop damage but improved weed control. Similar treatments with Lorox showed promising results.

A study of sampling procedures for estimating yields of mature weed infestations was carried out in Iowa. Precision indices were calculated for various sampling methods involving different fractions of the entire experimental plot. Loss of precision did not exceed 25 percent when as little as 40 percent of the plot was harvested in random segments. These techniques will permit efficient harvesting of mature weed infestations from herbicide tests and crop-weed ecology experiments.

Field studies were made in Missouri to determine the effect of row spacing on Clark soybean yields with and without pre-emergence treatments of Amiben at a rate of 3 lbs./acre. Abnormally high variability caused by uneven soil moisture conditions made the study very difficult to analyze. Because of this high variability there were no significant differences in yields of soybeans due to mechanical or chemical treatments.

Studies of the effect of three tillage methods on three weed control methods were conducted in Missouri for the fifth and last year. Corn yield was significantly lower in plots where the soil was prepared by conventional methods than plots where the soil was prepared by minimum tillage methods. There were no significant differences between any of the three weed control methods; (a) cultivate as needed, (b) pre-emergence 2,4-D and cultivate as needed, and (c) pre-emergence Atrazine. This indicates that the condition or smoothness of the soil surface has no effect on the action of the herbicides as determined under field conditions. The results indicate that a full season chemical weed control program is essential when using minimum tillage methods of soil preparation for corn production.

Field trials to determine the effect of rainfall (or irrigation) on weed control with granular and liquid formulations of 2,4-D were conducted in Missouri for the second year. Early applications of one and one-half inches of water immediately after pre-emergence application increased the weed yield significantly and caused the corn yield to be significantly less than the treatments where no water was applied. The pre-emergence applications of both liquid and dry formulations of 2,4-D suppressed the number of weeds. The corn yield was higher in plots receiving the granular formulation of 2,4-D.

Studies were made in Missouri to determine the effect of directed post-emergence applications of dalapon on corn. Four degrees of leaf protection were employed with two nozzle heights. The leaf protections used were (a) none, (b) leaves tied up, (c) shield leaf lifter, and (d) wire leaf lifter. A mechanical shield type leaf lifter was very effective in

minimizing the dalapon damage to corn. Wire type leaf lifters will have to be improved before they can be recommended for this application. Even when maximum protection was used by tying the leaves, there were visual damage to the corn plant, but this did not reduce the yield significantly. With the 3-pound rate of dalapon there was no apparent corn yield reduction when adequate leaf protection was provided.

A special long-boom sprayer was designed and constructed in cooperation with Crops Research Division, Southern Great Plains Field Station, Woodward, Oklahoma. The sprayer was constructed by using the chassis of a used self-propelled combine. A 100 foot boom is supported by a moveable frame in front of the combine. The spray tank was mounted in the center of the combine chassis. Modifications to the combine chassis included (1) moving the engine down and to the rear of the combine, (2) replacing the tires with Air Force B-50 bomber tires, and (3) increasing the tread width to about 10 feet. The sprayer can easily spray an acre per minute and is designed for use in open range areas too small for aerial applications.

A study was made in Missouri to determine the minimum mixing rates for applying several dry-formulation herbicides. A special spray stand was constructed to evaluate the performance of standard sprayer components when applying herbicides at different concentrations. The results of this study indicate that the following herbicides and minimum volumes of application are required for satisfactory sprayer performance when using a jet hydraulic agitator in a 55 gallon tank; Propazine 8 gallons per acre, Atrazine 12 GPA, NaPcP 15 GPA, Simazine 18 GPA and Linuron 20 GPA.

E. FORAGE HARVESTING EQUIPMENT

1. Field-curing studies of Coastal bermudagrass indicate that hay cut with rotary mower will dry faster than that cut with a sickle-bar mower, even if crushed or tedded. Due to many of the finely chopped particles not being picked up, the recovery yield for hay cut with the rotary mower was significantly lower than for that cut with the sickle-bar mower. Hay cut with the sickle-bar mower and crushed gave the fastest drying rate without a sacrifice in yield.

2. Studies on the optimum physical form and orientation of alfalfa for maximum drying rate showed that a 10-foot swath of forage, yielding 1.5 tons of dry matter per acre, raked into a conventional windrow would dry more slowly than when left in the swath. At dry matter yields of one ton per acre or less, the drying rate was not materially reduced when this practice was followed. Laboratory tests showed that forage given a severe mechanical treatment dried more rapidly than untreated forage. These mechanical treatments exposed more moist surfaces which gave a very rapid drying rate for a brief period, then slowed to a normal rate.

Hay wafering tests showed that many problems are encountered in this process. The operator must judge windrow density and moisture content and adjust speed and amount of water to be added. When variations in windrow are encountered, this becomes a demanding task. With increasing moisture content, about 10 percent (w.b.), increasing percentage of grass or increasing crop maturity, the production of wafers became more difficult. For the season, average production rate was two tons per hour with a commercial wafering machine consuming an average of four gallons of fuel per ton.

F. FORAGE SEED HARVESTING EQUIPMENT

1. Research was conducted on harvesting equipment to determine the efficiency of the cutting and feeding mechanisms in gathering crops for the purpose of improving the equipment and methods in order to reduce the seed shatter and damage losses. At Corvallis, Oregon, there were no investigations made during the year. At Clemson, South Carolina, the research was confined to making some minor alterations to the low cost row-crop corn-header combine attachment previously developed and observing its performance. The attachments are receiving good farmer acceptance and are now being manufactured commercially.

2. Improved Techniques for Harvesting Seed Crops. A survey of seed harvesting in the Willamette Valley of Oregon indicated that 50 percent of the small grass and legume seed produced is lost in the harvesting operation. In an effort to reduce the excessive seed losses, a scientific study was made under atmospheric controlled conditions in threshing crimson clover at Clemson, South Carolina. The study was made to determine the effect of cylinder speed and cylinder concave clearances on seed loss and damage. A rubber concave and cylinder bar threshing cylinder used in the tests produced excessive seed damage with a low percentage of unthreshed seed when the peripheral speed was 6,000 f.p.m. or higher, regardless of the concave clearances. At 4,000 f.p.m. the percentage of unthreshed seed was excessive even with the zero cylinder concave clearance. In tests involving a combination of five clearances and five peripheral speeds, best results were obtained with zero concave clearance and 4,500 f.p.m. peripheral speed.

At Corvallis, Oregon, research was continued on crimson clover harvesting. In an effort to reduce the high unthreshed seed loss in harvesting, a special rubber-covered cylinder and concave bar machine was compared to standard spike-tooth and rubber-covered angle bar threshing cylinders. Best results were obtained with the special rubber-covered cylinder bars when running 5,000 f.p.m. with a one-eighth inch concave cylinder bar clearance. The maximum threshing efficiencies were as follows: 80.5 percent for the special bar, 69.2 percent for the spike-tooth cylinder, and 64.5 percent for the angle-bar cylinder.

Research on belt threshing was initiated at Clemson, South Carolina, to determine seed loss, damage, and machine capacity. The unit will thresh by a rubbing action which will reduce seed damage. The first model of a test unit has been constructed and will be tested during the coming harvest season.

At both Clemson, South Carolina, and Corvallis, Oregon, research is underway on the development of a vertical rotating screen separator. If successful, the machine will have an improved separation efficiency and a higher capacity than that of a flat screen of the same size and area. The separating force can be regulated from zero up to 15 or more times that of the pull of gravity by adjusting the revolving speed of the screen. Preliminary test results look promising, however there are many problems yet to be solved before it is ready for general use. One of the major problems seems to be that of keeping the screen clean.

In a six-year study in methods of harvesting lotus or birdsfoot trefoil using many methods, windrowing the crop on clear plastic, then combining, gave the best results. The average yield by the several harvesting methods are as follows: 55 percent when windrowed on clear plastic, then combined. The yield was only slightly less for white plastic, kraft paper, and black plastic; 50.2 percent when put in very loose bales and later threshed through a combine; 49.5 percent when windrowed and threshed by using a combine with a suction attachment; 44.4 percent when windrowed, shocked and later threshed with a combine; 38.2 percent when windrowed on the ground and later threshed with a combine; 37.0 percent when defoliated and combined; 35.1 percent when combined direct without defoliation; 19.5 percent when combined direct with a suction attachment; and 9.3 percent when the crop was windrowed, baled and later threshed with a combine.

3. Optimum Moisture Content for Seed Harvesting. At Corvallis, Oregon, time of harvest research was continued with lotus and initiated with bluegrass and orchard grass. In lotus, the production of pure live seed per acre increased each time the crop was harvested until approximately 10 percent of the pods had shattered where 58.2 percent of the crop was saved; then the quantity of seed decreased until the entire crop had shattered. In the bluegrass harvesting research over a 26-day span, the bluegrass was harvested seven times. The highest percentage of pure live seed (74.9 percent) was obtained on the first cutting. This compares to an average of 55.8 percent for the farmer. Orchardgrass was harvested six times over a 19-day period with pure live seed ranging from 65.1 percent at first cutting up to 68 percent, and then down to 27.3 percent on the last cutting. This compares to a 55.8 percent pure live seed check over a farmer's two-year harvesting study. A battery-operated moisture meter was used to take readings on samples at each cutting and duplicate samples were oven-dried for correlation with the meter reading. These data will be used in plotting a curve for each crop for use with the meter in making on-the-spot moisture tests to be used as a guide to harvesting.

G. SEED CLEANING

1. Seed Cleaning Research Applied to Specific Problem Mixtures. At Corvallis, Oregon, problem seed mixtures were processed through the laboratory and reports and recommendations were made to the seed processors on how to handle them. The scientific method of microscopically measuring seed was used to determine the type of machine and the sizes of indent pockets or screens to use in order to exploit any dimensional differences in making a separation. Screen dams were successfully used to retard the flow of seed across a screen and to orient elongated seeds so that they would up-end and go through a round-hole screen. Some typical screen-dam separations were yellow star thistle from alfalfa; Alta fescue from Chewings fescue; wheat from safflower; quackgrass from brome grass; ryegrass from fine fescue; and barley from lentils. The vibrator separator that separates materials by sensing their shape and surface texture continued to give highly satisfactory results. It will concentrate quackgrass in ryegrass, orchardgrass, and fine fescue mixtures. It will separate curly dock from bluegrass; silver hairgrass from bentgrass; and multiple florets from singles in fine fescue grasses.

2. Centrifugal-Pneumatic Separator. There was no research conducted on the centrifugal-pneumatic separator during this reporting period. The plan for future work is to use a vacuum in lieu of air pressure as a means of removing lighter seed from the revolving screen.

3. Modification of Seed-Length Separators. At Corvallis, Oregon, special indent cylinders are being constructed to correspond to the microscopic measurements of seeds so that the cylinder will make a specific length separation of a seed and its contaminant. These special cylinders have been successful in making many separations which were not possible with existing equipment. Some of the separations using special indent cylinders were pigweed from alfalfa; yellow cress from Highland bentgrass; big mouse-ear from Astoria bentgrass; cocklebur from cottonseed; and sandspurry from Seaside bentgrass.

4. Development of Vibratory Feeders for Use in Studying Seed Cleaning and Handling Machinery. At Corvallis, Oregon, numerous feeding and metering devices are needed to feed several dozen prototype seed processing machines. The electric-powered pulsating magnet vibrator feeders are ideal for the purpose but are expensive. Inexpensive mechanical vibrator feeders were developed which can be shop-constructed at about one-eighth the cost of commercial vibrator feeders.

D. GRAIN DRYING

1. Studies are underway at Ames, Iowa, for determining the factors that enter into rational design of drying equipment and for developing quantitative descriptions of their relation to economic design. For example, during in-storage drying, overdrying and reabsorption of moisture puts excessive stresses on the drying bin. Costly failures can be avoided by either modifying the drying procedure or by modifying bin design. Equipment was set up to expose corn samples to constant temperature, constant humidity, and

constant air velocity. The samples were weighed periodically to determine the pattern of moisture loss. So far 10 tests have been made. Each test included four initial grain moistures and four air velocities, 16 samples in each test. Some tests have been continued for as long as four weeks. Each sample weighed about 50 grams at the start. The results so far seem to follow nearly the same pattern as found previously for grain sorghum. If this pattern is confirmed, it will lead to a better understanding of the mechanism by which the moisture leaves a grain kernel during drying. No further observations were made on pressures in bins due to expansion of rewetted corn. From previous observations such studies will have to wait for equipment in which the effect of flexibility of the bin can be taken into account.

2. Drying in Model Bins: Tests of drying shelled corn with various degrees of heating show a consistent relation between traverse time and depth of the drying zone. Four bins of corn with an initial moisture content of 22 percent were dried at various temperatures. The dewpoint was 45° F. for all four. The heated air temperature was such that the air temperature drop in going through the grain was approximately 9°, 20°, 41°, and 84° F. in the respective bins. The air in each bin dropped to approximately a constant temperature before it reached the top layer of grain during the early part of the drying period. The depth of the drying zone, the region in which the grain temperature is not constant, remains about constant until the top layer starts to dry. The depth of the drying zone in all bins was observed to be the distance the air moved in 1.4 seconds. This suggests that the depth of the drying zone is independent of the entering air temperature. It can be computed from this that the drying zone extends the entire depth of the bin when an airflow of 22 c.f.m. per bushel is used throughout the range of temperature used. If the volume of airflow is less than 22 c.f.m. per bushel, the bottom will be dried nearly to equilibrium before the upper layers start to dry.

3. The time limitation on deep bed or in-storage grain drying systems is dictated by grain deterioration which is caused primarily by the growth of molds and bacteria. Of secondary importance may be the respiration or growth of the seed itself. The factors which influence the rate of growth of the microflora are grain moisture, temperature, and the amount of physical damage of the grain. At Ames, Iowa, studies are underway toward evaluating the influence of these factors on the rate of growth of the microflora and subsequently the rate of deterioration. In 1962, the laboratory studies of carbon dioxide production was expanded to 96 samples. The range of temperatures was increased to from 35° to 110° F. and the range of moistures was from 16 to 28 percent. A pattern similar to that of last year was observed. That is, at moistures of 22 percent and above it appears that the grain respiration can be distinguished from the mold respiration. At lower moistures no consistent pattern has been detected. Some field-shelled samples and some hand-shelled samples were tested. The field-shelled samples had had mechanical damage comparable to corn from the usual harvest operations. The hand-shelled corn was free or nearly free of mechanical damage but otherwise like the field-shelled samples. The rate of CO₂ produc-

tion and presumably of deterioration was from two to three times as great in the field-shelled as in the hand-shelled samples. This suggests a potential improvement that might be accomplished if shellers could be designed to operate without damaging the corn.

I. FORAGE DRYING

1. Studies of wafer handling, drying, and storing properties showed that with the wafers made, gravity flow handling methods could not be used. Cribs do not permit sufficient ventilation to prevent molding when used as a storage for fresh wafers. Mechanical drying of wafers in a grain bin was slow because of the accumulation of fines and the resulting reduced air-flow. The use of a mechanical distributor did not alleviate the separation of wafers and fines. The slow movement of moisture from the center of dense wafers allows them to become dry on the outside and still contain too much moisture. Mold appeared on fresh wafers in 48 hours under controlled temperature and humidity conditions. These tests indicated that the only processing advantage of wafers is a reduction in the required storage volume. Future investigations will include physical quality, handling durability, the extent of surface drying, the rate of moisture removal, and the potential of pulse drying.

Samples of hay processed through a commercial expansion process, to free lignin, did not show an increase in digestibility when fed to sheep.

J. PELLETING FORAGE CROPS

1. Coastal bermudagrass dehydrating, grinding, and pelleting studies with full-scale equipment showed that the equipment should be operated at near maximum capacity for top efficiency. With the production rate varying from 1,068 to 1,267 pounds per hour (average 1,185), 6,923 cubic feet of gas and 149.9 kw.-hr. were required per ton of dry matter. With the production rate varying from 432 to 1,516 pounds per hour (average 1,112), 10,567 cubic feet of gas and 199.6 kw.-hr. were required per ton of dry matter. Thus, although the average rate was almost the same, the wide range in production rate required 51 percent more fuel and 33 percent more electric power.

Pelleting sun-cured Coastal bermudagrass was more difficult than pelleting dehydrated hay. The production depended largely on the quality of the hay. About 50 tons of sun-cured, baled Coastal bermudagrass hay, which in general was poor quality, was pelleted. The average production rate with a 30-h.p. motor on the pellet mill was 375 pounds per hour. When a 50-h.p. motor was installed, the average rate was 480 pounds per hour. About 4 1/2 tons each of high quality, 4-week-old and 6-week-old, excellent color Coastal bermudagrass was pelleted (50-h.p. motor on the mill) with an average production rate of 830 pounds per hour.

Grinding and pelleting energy studies on bermudagrass hybrids indicate that there was a significant difference in grinding energy requirements. However,

there was no significant difference in the pelleting energy. When the pelleting and grinding energy for these hybrids were added, there was no significant difference.

Systems of utilization of Coastal bermudagrass showed that more pounds of beef could be produced by dehydrating and pelleting than by any other method tested. Dehydrated and pelleted Coastal bermudagrass fed to steers in dry-lot produced 472 pounds of gain plus 2.22 tons of pellets (dry matter basis) per acre. Continuous grazing produced 451 pounds of gain and no surplus hay per acre. Rotational grazing produced 379 pounds of gain and 1.19 tons of poor quality hay per acre. Chopped, dehydrated hay produced 364 pounds of gain and 3.05 tons of hay per acre. Strip grazing produced 268 pounds of gain and 1.63 tons of poor quality hay per acre. Green chop produced 193 pounds of gain and 2.10 tons of hay per acre. Had all pellets and dehydrated hay been fed, and the same feed conversion rate maintained, the gains from these two systems would have been 783 and 764 pounds per acre, respectively. These results indicate that the value of 332 pounds of beef could be applied toward the costs of dehydrating and pelleting and the value of 313 pounds of beef could be applied toward the cost of dehydrating only.

K. Crop Storage Structures

1. Silo design criteria. Tests on two concrete silos at Beltsville showed that the walls of old silos could be restored and further acid damage prevented economically by lining with aluminum sheets. A combination of glue and blind riveting appears to be a satisfactory application method. Plain lap seams sealed better than handmade lock seams. After two years, the lining showed some acid etching and scattered punctures from silage forks. Small amounts of spoilage that occurred along some unsealed seams the first year were eliminated by resealing them with the neoprene-base glue used to apply the sheets.

Radioisotope determination of density at Beltsville, Md., continued with corn silage, rather than with grass silage, as in 1961. The point at which the silage was delivered in the silo was off center to determine if a dense pillar would be formed. At the point of delivery, as measured by gamma energy, the silage density was 16% more than the density at the opposite side of the silo. This change occurred at a very uniform rate. Potential sensitivity of the method was indicated by its detection of an increase in density of 3% due to tramping the silage. However, instrument stability is still troublesome, and at the greatest densities measured, 45 p.c.f. (pounds per cubic foot), possible error due to background radiation is large.

At Athens, Ga., work was started on measuring the gaseous transfer rate of silo staves. The oxygen transfer rate has been measured on a small number of concrete staves and additional work is planned for measuring the air and carbon dioxide transfer rates through many concrete staves and possibly other materials.

At East Lansing, Mich., studies of corn silage pressures in large diameter upright silos were continued. Pressures in a 30 x 60 ft. tower silo were measured for the third year by means of suspended panels. With poor silage distribution in 1962, maximum wall pressures were 630 p.s.f. (pounds per square foot) horizontal, and 300 p.s.f. vertical. These pressures were substantially greater than those of 1961 (400 and 150 p.s.f.) and occurred with nearly identical crop conditions and distribution. In 1960, with more uniform distribution, the pressures were 700 and 120 p.s.f. In 1961 and 1962 with poor distribution, horizontal pressures were less than in 1960 with uniform distribution. The position of the suspended panels was directly opposite the point of greatest silage depth, and pressures at that point may be much greater than those where the depth is uniform. Average moisture content of the silage has been nearly the same for the three years; however, distribution of the silage having different moisture contents may have contributed to the wide variation in pressures. Data such as these are essential for engineers to predict pressures developing in silos.

2. Heavily wilted silage storage. At Beltsville, Md., 2 years' tests of storing heavily wilted silage in two 10 x 40 ft. tile stave silos showed that high dry matter alfalfa (40.4 - 40.8% D.M.) can be safely stored in conventional silos. Total losses ranged from 4.6 to 11.8%. These comparatively small losses indicated that a strip of 14-pound asphalt felt or plastic is as effective as gaskets or calking compound in sealing the silo doors. The only apparent requirement is that the felt or plastic be kept in contact with the silo wall. The variation in the above losses also shows less spoilage occurred when plastic covers on the top of the silage were weighted with a foot or more of green forage, which was high in the center to maintain a tight seal between the plastic and the silo wall. Average temperatures in the 4 trials ranged from 89° to 93°F., with peak temperatures of 94°, 102°, 108°, and 112°F. These temperatures indicate good air exclusion. Feeding trials indicated the feed value of the silage was equal or superior to good quality hay.

3. Bunker silo tests. At Beltsville, Md., a bunker silo was loaded to a depth of only 3 feet with orchard grass wilted to 45% moisture. The silo was thoroughly sealed by lining the plank walls with plastic film which was folded in after tramping the edges and covered with a separate piece of plastic. The cover was then weighted with a 3-inch layer of sawdust. Although the amount of plastic used was twice that for a cover alone, loss by spoilage was insignificant. Temperatures were higher close to the surface, but none were excessively high. As an indication of microbiological activity, this may be significant nutritionally. The average density of the stored dry matter was 13.6 p.c.f. Wall pressures were obtained by means of suspended panels, and yielded these pertinent values per foot length of wall 3 feet high--lateral force: maximum 240 lb., settled 150 lb.; overturning moment: maximum 275 ft. lb., settled 150 ft. lb.

These data contribute to knowledge of requirements for designing bunker silos to economically store these silages.

Another bunker silo was filled to a depth of 8 feet with corn silage. Pressures on the side wall were measured during filling and settling. The maximum measured horizontal pressure was 170 p.s.f. and values per foot length of wall were--lateral force: maximum 890 lb., settled 600 lb.; overturning moment: maximum 2850 ft. lb., settled 1600 ft. lb.

4. Coastal Bermuda grass silage. At Athens, Ga., work was started during the year on a basic study of factors influencing the storage quality of Coastal Bermuda grass silage. In the laboratory, 588 one-half gallon glass jars were filled with this silage. Moisture content, density, level of corn additive, stage of maturity, exposure before sealing, kind and level of additive, air infiltration rate, and length of time of air infiltration were observed. All treatments were replicated and the results analyzed statistically. Dry matter loss and pH were determined for all samples and a chemical analysis made of 16 composite samples. Silage with 40 and 50% dry matter showed superior quality to silage with 30% dry matter. The optimum level of corn additive was about 100 lbs./ton although improvements were made by the addition of more corn. Silage quality was improved with a 24-hour delay in sealing the jars when compared to jars sealed immediately after filling. Quality also improved with stage of growth as the stage increased from three weeks to seven weeks. These results from both the exposure time and stage of growth are contrary to previous reports. The effects of air infiltration rates were significant but not as pronounced as originally expected. Additional studies of this type will be needed to fully determine and evaluate the factors influencing storage quality of Coastal Bermuda grass silage.

5. Hay wafer storage. At Beltsville, Md., storage of hay wafers was studied in a variety of plain and forced air bins. Storage densities up to 22.8 p.c.f. (20 p.c.f. dry matter) occurred with well consolidated alfalfa wafers, but with poor crop and wafering conditions this was reduced to as low as 13.7 p.c.f. (12 p.c.f. D.M.). Safe storage moisture content for alfalfa wafers under Beltsville conditions was 14%.

It was not possible to control the movement of these wafers from storages with bottom doors or trenches. Difficulties experienced indicate the need for additional study to determine the design requirements for bins that can be unloaded with mechanical equipment.

6. High moisture shelled corn. At Ames, Iowa, studies were undertaken on the effects of airtightness, moisture content, and initial infestation of microflora on the storage process of high moisture shelled corn. Six of the eight 200-bushel airtight storage tanks were filled with 33% moisture shelled corn. The other two with 29% moisture shelled corn. The oxygen in the tanks was depleted within 6 to 8 hours after the tanks were sealed. The carbon dioxide concentration increased to about 97% in about 70 hours

accompanied by a 5 to 10°F. temperature rise. The 33% moisture corn produced about 11 grams of carbon dioxide per kilogram of dry matter in the tanks in 12 days. No further production was detected except that produced when measured air "leaks" were introduced. This initial production was almost all anaerobic and it was estimated that this activity resulted in about a 1% loss of dry matter. A 2.5 to 3.0 percent dry matter loss was measured in all tanks over the storage period. The maximum measured "leak" of 50 cubic feet of air per day for 16 days in two periods of 8 days each did not appear to have created any spoilage. It was estimated the tanks contained about 150 cubic feet of gas. The oxygen introduced was converted to carbon dioxide within a few hours after it was introduced. The carbon dioxide concentration approached about 20% with "leak". The no leak tanks also approached 20% carbon dioxide concentration at the time of unloading.

L. Electromagnetic Radiation Equipment for Seed Treatment

1. Radiofrequency Energy for Insect Destruction and Seed Treatment for Grain and Forage. Investigations of potential use of radiofrequency (RF) energy for insect destruction and improvement of seed germination were continued in cooperation with the Departments of Agricultural Engineering, Entomology, and Agronomy at the Nebraska Agricultural Experiment Station. Cooperation on some phases of the work was furnished by the Crops Research Division, ARS, USDA; Eastern States Farmers' Exchange, Inc., Buffalo, New York; the Research Department of the Asgrow Seed Co. and the University of Idaho.

Experiments with stored-grain insects continued to show that all developmental stages of several species were controlled by treatment of infested wheat for a few seconds. The treatments did not damage the germination of wheat if the moisture content was low enough for safe storage. The exact nature of the lethal action has not been determined, but selective heating of the insects in the radiofrequency electric field appears to be a likely explanation. Treatments produced marked weight losses in the insects. High field intensities were generally more effective than low field intensities in killing insects. Treatments at frequencies of 10 and 40 megacycles were about equally effective in controlling dermestid larvae and adult rice and granary weevils when field intensities were adjusted to provide equal heating rates for the two frequencies. Somewhat longer exposures were required to control adult rice weevils and lesser grain borers inside wheat kernels than when the same insects were not shielded by the kernel. Physiological studies on yellow mealworms revealed no differences in amino acids extracted from RF-treated and untreated insects.

Treatments which were very effective in breaking dormancy in DuBois winter oats in 1960 were not damaging to the seed which was retested after 2 years in uncontrolled storage.

Work will be continued on insect control and seed treatment studies with emphasis on learning basic explanations for observed effects due to RF electric field exposure.

Tests on seed lots of several alfalfa varieties showed that germination was effectively increased by RF electrical treatments which reduced the percentage of hard-seeds. Effectiveness of treatment in lowering hard-seed content increased as seed moisture content decreased. Germination response at frequencies of 5, 10, and 39 megacycles appeared to be about the same. Treatment increased the rate at which the seed absorbed water. Microscopic staining tests revealed no cracks in the seed coat due to treatment. Quality of RF treated seed held up as well as untreated seed after 4 years in favorable storage. Quality of treated alfalfa, red clover, and ladino clover seed remained as good as untreated seed when tested after 2 years in uncontrolled storage, and hard-seed content was lower in treated samples.

Treatment was not effective in lowering hard-seed content of sweetclover seed lots unless they were dried to very low moisture levels.

Radiofrequency, infrared, and glow-discharge electrical treatments of Ranger, Narragansett, and DuPuits alfalfa seed lots were equally effective in reducing hard-seed content, increasing water sorption, and increasing the seed respiration rate. The latter treatment produced accelerated emergence for some samples in greenhouse sand emergence tests.

RF treatment appeared to improve germination and emergence of three Kentucky bluegrass seed lots tested during the year. Emergence of treated samples was higher for a lot exhibiting a high degree of dormancy. The number of seeds sprouted at 5 days was significantly higher for treated samples in the two other seed lots.

Studies will continue to evaluate effectiveness of RF energy for improving germination and emergence characteristics of seed, and efforts will be made to learn the basic reasons for observed effects of RF seed treatment.

2. Glow-Discharge Radiation Treatment of Forage and Grain Seed. Studies on effects of electric glow-discharge radiation on seeds and plant products have been continued at Knoxville, Tennessee, in cooperation with the Departments of Agricultural Engineering and Nutrition of the Tennessee Agricultural Experiment Station and the Crops Research Division, ARS. In cooperative tests comparing glow-discharge, radiofrequency, and infrared treatment of three alfalfa seed lots containing high percentages of hard-seed, all three types of treatment were equally effective in lowering hard-seed content and producing a corresponding increase in germination. Methods were developed for measuring the conductivity of leachate solutions for alfalfa seed samples. Leachate conductivity, water sorption, and oxygen uptake were increased by all three types of treatment. In addition, glow-discharge treatment accelerated emergence of one variety in greenhouse sand emergence tests.

At Pullman, Washington, in cooperation with the Departments of Agricultural Engineering and Agronomy of the Washington Agricultural Experiment Station, glow-discharge radiation was also effective in reducing the hard-seed percentage of red clover at both high and low moisture contents. Hard-seed percentages in sweetclover seed lots, however, were lowered only when seed moisture content was very low.

Samples of Kentucky bluegrass seed exhibiting a high degree of dormancy were subjected to ultraviolet and heat treatments in a hot water bath, as well as glow-discharge radiation, at Knoxville, Tennessee, in cooperative studies with Crops Research Division personnel at Beltsville, Maryland. A 180° F. heat treatment significantly increased emergence at both 11- and 27-day counts. These studies will be continued in 1963.

In experiments to help explain changes in soybeans caused by exposure to an electric glow-discharge, Ogden soybeans were ground into meal and used as the protein supplement of a diet fed to rats in an experiment conducted in cooperation with the Nutrition Department of the University of Tennessee College of Home Economics. The animals fed the treated bean meal showed a 15 percent higher gain than the animals fed the untreated meal. The experiment is to be continued using different levels of treatment intensity.

Research continued in cooperation with crops Research Division and the Washington Agricultural Experiment Station to determine effects of glow-discharge electrical seed treatment on wheat. Field trials on spring and winter wheats have shown no significant differences in emergence or plant height due to treatment, except where the treatment was damaging. A small increase in emergence rate was noted in one spring wheat variety.

3. Electrostatic Seed Separation. At Corvallis, Oregon, a study was conducted with the electrostatic machine to determine if seed mixtures that could not be separated with the conventional machines (which sense only the size, shape, length, and density of seeds) could be separated by their differences in electrical conductivity. The project was terminated in 1962 but the electrostatic machine was used on some twenty problem seed samples, four of which were considered successful. Witchweed seeds were removed from two types of sandy soil; inert matter and seed heads were removed from onion seeds; and pink bollworms were removed from cotton gin trash.

M. Plant and Product Environmental Equipment

1. Electric Equipment for Soil Warming and Plant Growth. Investigations were begun in Indiana to determine the fundamental requirements for installation and management of electric soil heating cable systems to maintain suitable growth conditions for turf in heavy-use areas. This is in cooperation with the Purdue University Departments of Agronomy and Agricultural Engineering.

Preliminary trials showed that temperatures of 65° F. developed through under-turf heating using electric heating cables produced vigorous bluegrass growth in excess of that desired in a ten-day period in early March 1962, while unwarmed turf remained dormant.

A turf heating installation, 20 x 60 feet, was made in late October. Preliminary results show that, while bluegrass sod remained dormant on unheated soil, root extension was 3 - 5 inches by December 31 on heated areas. Top growth was observed where a plastic cover was used in addition to supplementary heat and in uncovered areas having 10 watts per square foot or more of heat applied. Rooting was more uniform in the plastic covered areas with wintertime desiccation of leaves reduced so that turf remained essentially a normal green even at extreme low temperatures.

2. Solar Equipment for Grain Drying. The results of three years (1960, 61, and 62) of fall in-storage drying tests of sorghum grain have shown that a solar supplemented system resulted in a saving of 55, 77, and 48 percent, respectively, in energy costs as compared to the natural air drying system. No additional heat was needed by the solar supplemented system. However, the natural air system required added heat from liquefied petroleum source during the 1961 tests.

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A Summary of Current Program and
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GRAIN AND FORAGE RESEARCH

of the
United States Department of Agriculture
and cooperative agencies

Section B

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last year. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

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Washington, D. C.
December 31, 1963

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II. NUTRITION, CONSUMER AND INDUSTRIAL USE RESEARCH

CEREAL STARCHES - INDUSTRIAL UTILIZATION

Northern Utilization Research and Development Division, ARS

Problem. Starch accounts for about two-thirds the weight of all grains. Finding new, large-volume outlets for starch would, therefore, result in substantially increased consumption of cereal grains. Of the 4.5 billion pounds of cereal starch now produced, about 2.7 billion pounds is used ultimately in food products, and increases would be expected to follow population growth. However, the remaining 1.8 billion pounds find industrial outlets that offer opportunities for increases at a rate greater than that of population growth. Because starch must compete with products derived from nonagricultural sources, these opportunities can best be realized by a program of research designed both to maintain the competitive position of starch in its current uses and to develop economical new industrial uses.

New outlets for cereal starches and flours equivalent to over 200 million bushels of grain by 1975 can be envisioned if basic research and development on several types of chemical and physical modification of starch and flour now in the experimental stage or anticipated can be prosecuted to successful conclusion. About 150 million bushels could be required for new products for the pulp and paper industries and for the building and construction industries, and about 10 million bushels each for other industries such as the chemical, petroleum, mining, textile, plastics, coatings, and packaging industries. New outlets for starch that appear very promising include use of modified starches as wet-strength additives for paper, water-resistant adhesives, coatings, and foamed products, and of starch-derived pulps as an integral part of high-quality paper. In addition, if the competitive position of starch is successfully maintained through improvement by research, additional consumption would be expected by 1975 from participation in markets for 100 million bushels of grain resulting from normal growth of existing industrial outlets for starch and flour such as paper, textiles, packaging adhesives, drilling muds, and building materials.

To accelerate realization of these goals, more information is needed on the physical and chemical properties and chemical reactions of cereal starches, on economical methods for effecting desired physical and chemical modifications and on product evaluation and development. In addition, still further new markets for cereal starches should be possible from an adequate program of fundamental and exploratory research to discover new concepts, principles, and reactions leading to new processes and products for future development.

USDA PROGRAM

The Department conducts a continuing, long-range program of research involving analytical, organic and physical chemists and chemical engineers engaged in basic, applied and developmental studies on the chemistry of cereal starches and their conversion to useful industrial products.

The Federal scientific effort for research on cereal starches totals 55.0 professional man-years. Of this number 11.0 are devoted to chemical composition and physical properties and 44.0 to new starch chemical derivatives and their evaluation.

Research at Peoria, Illinois, on chemical composition and physical properties (9.2 professional man-years) involves fundamental research on reactions of starch and dextrose in nonaqueous solvents. Research contracts under this subheading (1.8 professional man-years) are in effect with the University of Arizona, Tucson, Arizona, for basic studies on the reaction of starch with mercaptans (.6 professional man-year) and with acetylene (.5 professional man-year); and with The Johns Hopkins University, Baltimore, Maryland, for basic research on the reactions of starch in fluid dynamic media (.7 professional man-year).

Research at Peoria, Illinois, on new starch chemical derivatives and their evaluation (32.6 professional man-years) involves basic and applied studies on various types of chemical products derived from starch and dextrin and in evaluation of these products for various industrial uses such as pulp and paper products, plastics, coatings, organic chemicals and stable viscosity agents. During the reporting period research was discontinued on production of hydroxymethyl furfural from starch and on use of dialdehyde starch as a raw material for new chemical products. Research contracts under this subheading (11.4 professional man-years) are in effect with the University of Minnesota, St. Paul, Minnesota, for studies on reactions of dialdehyde starch in solution (.4 professional man-year); with Ohio State University, Columbus, Ohio, for research on synthesis of amino derivatives of starch (1.2 professional man-years); with the State University of New York, Syracuse, New York, for evaluation of crosslinked hypochlorite-oxidized starches in papermaking (.3 professional man-year); with Battelle Memorial Institute, Columbus, Ohio, for evaluation of allyl dialdehyde starch in coatings and resins (2.0 professional man-years) and for developmental research on starch and other cereal grain xanthides (6.2 professional man-years); and with Stanford Research Institute, Menlo Park, California, for research on graft copolymers of cereal starches with vinyl-type monomers (1.3 professional man-years).

The Department also sponsors research on cereal starches conducted by foreign institutions under grants of PL 480 funds. Research on chemical composition and physical properties involves grants to the Institute of Fibres and Forest Products, Jerusalem, Israel, for research on hypohalite

oxidation of cereal starches (5 years, 1958-1963); University of Birmingham, England, for research on starch structure as revealed by interaction of starch and enzymes (5 years, 1959-1964); National Institute of Hygiene, Paris, France, for research on proteolysis inhibiting effects of cereal starches and flours (3 years, 1961-1964); National Institute of Agronomic Research, Paris, France, for research on changes induced in starch by gamma irradiation (4 years, 1961-1965); and Scientific Institute for Chemistry and Biochemistry, Milan, Italy, for research on glucopyranose rings in starches and dextrans (5 years, 1962-1967). New starch chemical derivatives and their evaluation involves grants to the Arthur D. Little Research Institute, Musselburgh, Scotland, for research on glucose-derived polymers (4 years, 1959-1963); Hebrew University, Jerusalem, Israel, for studies of methods for preparing fluorine derivatives of starch (3 years, 1961-1964); Institute of Industrial Chemistry, Bologna, Italy, for studies on fatty chemical derivatives of starch dextrans (5 years, 1960-1965); National Institute of Technology, Rio de Janeiro, Brazil, for research on phosphorus- and sulfur-containing cationic starches (5 years, 1962-1967); and Ahmedabad Textile Industries Research Association, Ahmedabad, India, for research on starch-gum copolymers prepared by codextrinization (5 years, 1963-1968).

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Reactions of starch and dextrose in nonaqueous solvents. Yields of pure disorbitylamine hydrochloride have been increased to 64 percent of theory. The procedure was shown to be generally applicable to aldoses. Preliminary cost estimates for disorbitylamine suggest a selling price of about 50 cents per pound (without provision for recovery and sale of by-products). A survey of market potential conducted by the ERS representative at NU indicated a potential market for organic chelating agents of about 30 million pounds per year. In view of its probable selling price, disorbitylamine appears to merit further consideration for end uses such as textile sequestrants and biodegradable detergents. Derivatives of disorbitylamine of particular interest are those combining sequestration and surface activity. Another product, isomaltol, has attracted the attention of a commercial firm, which has indicated intention to produce this product under NU patents.

Further study of complexes of carbohydrates and alkali metal hydroxides showed that in the nonaqueous solvent, N-methyl-2-pyrrolidone, such complexes are at least 85 percent in the alcoholate form, whereas when these complexes are formed in aqueous media, they are not alcoholates but rather simple adducts. Studies on formation of complexes of alkali metal salts and carbohydrates in alcoholic media have clarified the effects of salt concentration and of the presence of water. Complexes of the metal salt with two carbohydrate molecules are favored by anhydrous conditions and

low salt concentration. With higher salt concentrations and up to 5 percent of water, the ratio of salt to carbohydrate in the complex increased. In the presence of water, alkali hydroxides behaved like salts; e.g., complexes ranged from 1 sucrose·3 NaOH to 2 sucrose·1 NaOH.

2. Reactions of starch with acetylene and mercaptans. In contract research at the University of Arizona, statistical analysis of experimental data revealed optimum conditions for five variables (time, temperature, pressure, proportion of KOH, and solvent ratio) in the reaction of acetylene with starch.

Starches were observed to differ in reactivity to acetylene. For best results corn and sorghum starches required an activation treatment which was not necessary for wheat, waxy corn or waxy sorghum, high-amylose corn starch, potato starch and corn amylose. Vinyl starches of 0.6 to 1.1 degree of substitution were soluble in methanol, acetone, dioxane and tetrahydrofuran but not in water, ether, benzene and carbon tetrachloride. Films from polymers of vinyl amylopectin and of vinyl high-amylose corn starch were brittle.

Other contract studies at Arizona on glucose-mercaptan reaction products yielded dark-colored materials showing some promise as adhesives.

3. Reactions of starch in fluid dynamic systems. Early results of contract studies at Johns Hopkins University indicate that reactions of starch with propylene glycol or dimethylsulfoxide at temperatures above 100° C. merit further study in fluid flow systems.

4. Hypohalite oxidation of starches. At the Institute for Fibres and Forest Products Research, Jerusalem, Israel, a chemical equation has been developed on the basis of kinetic data that describes the oxidative reaction, and the influence of different process conditions on the rate of reaction has been determined. Analytical determinations on oxidized starches have revealed the amount of starch polymer cleavage and the number and type of new functional groups that result from oxidations under different conditions. This work is providing a basis for the correlation of chemical structure with useful physical and chemical properties so that products of uniform quality can be routinely made, and so that products of improved quality for specific end uses can be obtained by altering process conditions. This research, which was performed under a PL 480 grant, has been completed.

5. Starch structure. In studies conducted by scientists at the University of Birmingham, England, under a PL 480 grant, reversible reactions between large molecules are being investigated by sedimentation and electrophoresis methods with the aim of interpreting the interaction of starch with its associated enzymes. Procedures were developed for successful enzymatic synthesis of model starch molecules of exceptionally uniform molecular

weight distribution. At the "Giuliana Ronzoni" Scientific Institute of Chemistry and Biochemistry, Milan, Italy, studies under a PL 480 grant on amylose deuteration have confirmed that the hydroxyl hydrogen atoms of amylose are exchanged completely with deuterium. Tentative assignment of infrared absorption bands for freeze-dried cyclodextrins, amylopectins, and amylose has been made.

6. Proteolysis inhibition by starch. A water-soluble, heat-labile, trypsin inhibitor was found in wheat flour as well as in corn, barley, rye, oats, rice, millet, and buckwheat. No inhibitor was detected in wheat bread, and only a small amount in rye bread. Starches showed no inhibiting activity, although their adsorption of proteolysis products caused some interference in the application of the assay method which was developed. This research is being performed by the National Institute of Hygiene, Paris, France, under a PL 480 grant.

7. Effects of γ -radiation on starch. Results of studies now in progress under a PL 480 grant at the National Institute of Agronomic Research, Paris, France, indicate (1) that glucose units are so altered by γ -irradiation that they no longer can yield 5-hydroxymethyl furfural; (2) that with increased irradiation more starch becomes soluble in water and the fraction of starch comprising chains of less than 14 glucose units increases; (3) that susceptibility to the action of α -amylase increases; and (4) that increased amounts of ionizable groups are formed. These results are consistent with the interpretation that γ -irradiation causes chemical changes at OH groups, ruptures starch chains, breaks hydrogen bonds and alters the starch granule membrane. The water content during irradiation appears to play a leading role in the development of these changes.

B. New Starch Chemical Derivatives and Their Evaluation

1. Studies on starch xanthates and xanthides. Studies on starch xanthates and xanthides (called "cereal pulps" in last year's report) are establishing a sound basis for development of a practical process for their preparation and use in paper. A semicommercial-scale trial run was successfully performed at Forest Products Laboratory in which an unfilled bond-type paper containing 12.5 percent of starch xanthide was produced. Dry tensile and bursting strengths of the product were 60 percent and 120 percent greater than the respective values for the control. Wet strength was increased 500 percent and brightness decreased about 10 percent. Feasibility of large-scale use has thus been demonstrated, and several aspects of such use requiring special attention, such as pH control, mixing, and odor problems, have been identified.

Investigations on the conversion of cereal xanthate to xanthide with hypochlorite have revealed conditions for reducing the oxidant requirement from 1.5-2.0 moles to about 1.1 mole per xanthate group. Conditions have also been found for efficient use of hydrogen peroxide as the oxidant. No

metal ion catalyst is needed and the oxidant requirement is close to theory. An automatic system for controlling and recording pH and redox potential during oxidative coupling of xanthate was devised.

Xanthates may be added in solution to a wood pulp suspension and then crosslinked to insoluble xanthides (in situ formation) or they may be separately insolubilized and added to the pulp (ex situ formation). In laboratory studies, addition of xanthide prepared ex situ gave variable results. However, exploratory experiments have provided leads to techniques that may result in consistently good wet and dry strength increases by ex situ formation of xanthide. In use of xanthide formed in situ, freshness of xanthate and presence of alum favorably influenced retention. Wet strength of xanthide papers was improved by heating or extended low-temperature equilibration.

A contract, covering development of a practical process for continuous production of cereal xanthate and for optimum use in paper of xanthide formed ex situ, has been negotiated with Battelle Memorial Institute.

2. Evaluation of dialdehyde starch (DAS) and derived products. Extensive evaluation studies on DAS-betaine hydrazones (cationic DAS) showed that 2.5 percent of cationic DAS produced a wet-strength increase equal to that obtained with 2.5 percent each of ordinary DAS and cationic-starch retention aid. Addition of more than 2.5 percent of cationic DAS gave greater increases than were possible with DAS plus retention aid. All of the desirable properties imparted to paper by DAS plus retention aid are also imparted by cationic DAS. Simultaneous cationization and dispersion of DAS were readily achieved by heating briefly at 92° C. a suspension of DAS to which the betaine was added. Large-scale trials of cationic DAS in bag paper and toweling were made at Forest Products Laboratory. The results were very successful. Retentions of 84-90 percent of the cationic DAS were achieved.

Birch plywood adhesives prepared by reacting casein and DAS had rapid cold set and good dry strength. Dry shear strength and wet strength (after 48 hours soaking in cold water) exceeded values for commercial casein glue. The DAS-casein glue bond also resisted delamination in boiling water. However, poor bonding was obtained with Douglas fir, presumably because penetration was decreased by the resins present in the wood. Light sanding was found to improve greatly adhesion with Douglas fir, and preliminary tests of isopropanol as an additive to the glue to promote penetration appeared promising. For this development to achieve success it will be necessary to solve the problem of adhesion to Douglas fir, which represents the major portion of the potential market. In 1960, about 270 million pounds of adhesives were used by the plywood industry. Casein adhesives, if crosslinked by DAS, may be suitable for exterior use. Such use would represent a substantial new market for DAS. Present results also indicate

that DAS has potential for improvement of animal blood and soy flour adhesives, which together make up the bulk of the 120 million pounds of protein adhesives now used in plywood.

Studies at the University of Minnesota were continued on partially oxidized corn starch in an effort to determine the mode of attack of periodate on starch. Borohydride reduction with subsequent hydrolysis of 29 percent and 43 percent periodate-oxidized starch yielded glycerol, erythritol, 2-O- α -D-glucopyranosyl-D-erythritol, and a series of erythritol glucosides of higher oligosaccharides. Two different disaccharide fractions were also obtained which are being characterized.

At Battelle Memorial Institute, allyl DAS was found to have the solubility and viscosity properties and compatibility with plasticizers required for commercial lacquers. Films cast on tin plate and cured for 30-60 minutes at temperatures from 140° to 400° F., were hard but had inadequate strength when unsupported. A molded product obtained by copolymerization of allyl DAS and polyethylene glycol dimethacrylate had promising properties. Studies on chemicals from DAS were discontinued, except for preparation of materials for use in the contract work at Battelle.

In contract research at the State University of New York, hand sheets were prepared with two levels of addition of dialdehyde wheat starch, 90-93 percent oxidation, and dialdehyde corn starch, 10 percent oxidation. Tests of the products as wet end additives are, however, not yet complete.

Standard dress shoes with soles of experimental DAS-tanned leather (prepared during contract research by Armour Leather Company) were manufactured according to Quartermaster Corps specifications in September 1962. These were cross-matched with standard dress shoes and are being given service tests at the Quartermaster Field Evaluation Agency at Fort Lee, Virginia. A final report on the performance of the experimental shoes should be available by the middle of 1964.

3. Chemical products from starch and dextrin. Several new acetals of starch, amylose and glucose were prepared. They showed a very wide range of properties depending on the carbohydrate and the degree of substitution. Low D.S. (degree of substitution) starch-dihydropyran acetals appeared to have good properties as warp sizes for synthetic yarns.

So far, attempts to improve the coagulant properties of starch by introducing differing amounts of acrylamide groups into cationic starch have not been successful. Very low D.S. (below 0.1) cyanoethylated starches and dextrans had promising properties as paper-coating adhesives and gave better bonding than commercial starch adhesives for coatings containing low (40 percent) solids content.

Polyol glycosides (from reaction of starch and a glycol) were polyetherified by reaction with propylene oxide. Rigid urethane foams, made from the

polyethers by the prepolymer method, had densities of 1.7 to 2.1 pounds per cubic foot and dimensional stability and compressive strengths sufficiently good to justify more extended study and evaluation. Rigid foams based on polyethers of starch polyol glycosides appear to have commercially acceptable properties. Cost estimates indicate that they could be produced at competitive prices. Since the world market for rigid foams is expected to exceed 110 million pounds by 1965, success in this development could lead to a significant new market for starch.

In contract research at Ohio State University, several aminated amylose derivatives have been prepared.

At the Hebrew University, Jerusalem, Israel, several model compounds such as β -tetraacetyl glucose-6-bromohydrin have been prepared and exchange reactions between the halogen in these models and various inorganic fluorides are being studied to provide guidelines for introducing fluorine into starch. In studies at the National Institute of Technology, Rio de Janeiro, Brazil, starch was reacted with thioglycolic acid in the presence of sulfuric acid catalyst to obtain starch thioglycolate. This product was reacted with ethyl iodide to yield the sulfonium derivative which appeared to have cationic properties. Scientists at the Institute of Industrial Chemistry, Bologna, Italy, have made many fatty ester and some fatty amine derivatives of fractions of corn dextrin. The results are promising for locating a possible source of biodegradable detergents utilizing waste fats and surplus cereal grains. These studies are being conducted under PL 480 grants.

4. Evaluation of starch derivatives in paper and paper products. Research on new chemical products from starch is supported by evaluation studies to determine the quality and performance of these products in applications in the pulp, paper and paperboard industry. During the reporting period tests were conducted, for example, with starch xanthates and xanthides, cationic dialdehyde starch, and cyanoethylated starch. Results of the evaluation studies are reported in conjunction with the general discussion of research on the specific starch product.

5. Polymers based on carbohydrates. Investigators at the Arthur D. Little Research Institute, Musselburgh, Scotland, have prepared a new water-soluble glucose polymethacrylate as well as the first known high molecular weight polymer of a glucose-derived vinyl ether. Other novel polymeric products synthesized include a series of polyphenyl esters derived from bisphenol A and carbohydrate diacid chlorides and a series of nylon-6,13-type polyamides obtained by reaction of brassyloyl chloride and carbohydrate diamines. Several of the nylon-6,6-type polymers reported previously are being evaluated by British industrial firms for use in fibers and as adsorbents for removal of protein tannin haze in beer. This work is being conducted under a PL 480 grant.

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WHEAT - INDUSTRIAL UTILIZATION
Northern Utilization Research and Development Division, ARS

Problem. Wheat traditionally commands a higher price than corn. Since the starch content and starch properties of these two cereals are similar, new industrial uses for wheat must rely on advantages to be obtained from other components. Wheat flour is a mixture of starch, protein, gums, fiber, and fat. Because of the simultaneous presence of these basic ingredients, opportunities are promising for development of a wide variety of industrial products from wheat flour that would be expected to have properties and uses different from those of related products derived from refined starch. The problem is to find means for economical modification and reaction of these ingredients with each other and with other chemicals in order to realize the potential of the combinations.

Basic research now being conducted by the Department points to new potential industrial uses for cereal starches and flours that could consume over 200 million bushels of grain by 1975. Among potential outlets for wheat flour are sizes for many special grades of paper, cereal pulps that would form an integral part of such papers, and plastic or foamed compositions for hardboard and insulating boards. The opportunity for successful realization of these possibilities is enhanced by recently developed fine-grinding and air-classification milling techniques that permit the composition of flour to be varied over wide ranges. These techniques are now satisfactory for soft wheats, but ways must be found to adapt them to hard wheats which constitute 93 percent of the wheat remaining after current needs have been met.

Wheat flour could achieve its share of potential new markets more rapidly, and discovery of additional new uses under both public and private research programs would be facilitated, if more information were available on the basic physical properties and chemical reactions of flour and its components, on tempering and milling techniques, and on processing methods for economical conversion of flour to desired end products.

USDA PROGRAM

The Department conducts a continuing long-range program of research involving analytical, organic and physical chemists, chemical engineers and structural biologists engaged in basic studies of the chemical and physical properties of wheat, flour, flour fractions, and protein components and in applied research leading to new and improved wheat products for industrial use.

The Federal scientific effort for research on industrial utilization of wheat totals 47.2 professional man-years. Of this number 14.4 are devoted

to chemical composition and physical properties; 20.6 to industrial chemical products; and 12.2 to processing technology.

Research at Peoria, Illinois, on chemical composition and physical properties (12.0 professional man-years) includes separation, characterization and chemical reactions of the component proteins of wheat gluten. Research contracts (2.4 professional man-years) are in effect at Purdue University, Lafayette, Indiana, for fundamental studies of the alkaline desulfurization of gluten (.8 professional man-year); and Armour Research Foundation, Chicago, Illinois, for investigation of methods for controlled hydrolysis of gluten (1.6 professional man-years).

Investigations on industrial chemical products conducted at Peoria, Illinois, (17.5 professional man-years) involve preparation and evaluation of new types of water-soluble and water-insoluble flour derivatives for industrial use. During the reporting period laboratory studies on hydrophilic flour derivatives, such as sulfated wheat flour, was placed in abeyance to permit strengthening of the research effort on xanthates and xanthides of starch, wheat flour and other cereal products. Research contracts (3.1 professional man-years) are in effect with Stanford Research Institute, Menlo Park, California, for basic research on graft copolymers from wheat flour and starch (1.4 professional man-years); and Iowa State University, Ames, Iowa, for studies on development of improved adhesives from wheat gluten by reaction with dialdehyde starch (.8 professional man-year) and for engineering studies on use of pneumatic fluidization to effect acid modification of flour (.9 professional man-year).

Processing technology research at Peoria, Illinois, (11.6 professional man-years) involves studies on conditioning and milling of wheat, air classification of flours, and reduction of viable microorganisms in wheat flour. A research contract (.6 professional man-year) with Kansas State University, Manhattan, Kansas, is concerned with study of the mechanism of enzyme formation during wheat malting and relationship of the information developed to control of enzymes and their action during milling and processing of wheat.

The Department also sponsors research in this area conducted by foreign institutions under grants of PL 480 funds. Research on chemical composition and physical properties involves a grant to the Weizmann Institute of Science, Rehovot, Israel, for synthesis and study of polypeptides having amino acid compositions related to wheat gliadin and corn zein (4 years, 1960-1964). Research on processing technology involves a grant to the Research Association of British Flour Millers, St. Albans, England, for investigations on quantitative measurement of properties of wheat that change significantly during conditioning (4 years, 1961-1965).

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Characterization of wheat gluten proteins. Titration studies on gluten showed that only about 10 percent of the amino acid residues contributed ionizing groups. These groups, in descending order of frequency of occurrence, were carboxyl, tyrosyl, imidazole, lysyl, α -amino and sulfhydryl. The ionization constants of these groups were all normal, showing absence of interaction or structural anomalies in dilute solution. Guanidyl groups were not titrated since the pK of this group is greater than 13. By chromatography, reduced-alkylated glutenin was separated into three fractions, each containing two of the six major components present in reduced glutenin. Amino acid analysis of the three chromatographic fractions revealed generally similar compositions, with the major portion (ca. 70 percent) of the residues accounted for by glutamine, proline, and glycine. Significant differences between the fractions were observed in the content of arginine, histidine, alanine, valine, and phenylalanine. These differences establish that glutenin is composed of several distinct polypeptide chains.

The molecular weights of native and reduced gamma-gliadin were obtained by sedimentation analysis in 4 M guanidine hydrochloride. A molecular weight of 26,000 was obtained for both the native and reduced proteins, indicative of the single chain structure of gamma-gliadin. This is in agreement with the observation of only one component after starch gel electrophoresis of reduced protein. A minimal molecular weight of 25,000 was calculated from the amino acid analysis of the gamma component. Further characterization of gamma-gliadin showed that aspartic acid occupies the N-terminal position and serine the C-terminal position. A probable sequence in the C-terminal portion of gamma-gliadin isLeu . Thr . Gly . Ser.COOH.

Information on aggregation, ionic interaction, solubility, structure, reactions and other physical and chemical properties of the gluten proteins is basic to understanding and control of properties and to chemical modification of gluten and derived products, as such or in flour. Research during this period has made important new contributions to such fundamental information.

2. Chemical reactions of wheat gluten. Water-soluble, synthetic polypeptides containing glutamine residues were insoluble in water at low pH unless a small amount of urea was present. Since the polypeptides retained helical formation in the urea-containing solutions, only side-chain amide associations appear to have been disrupted. Solubility of gliadin in solutions at increased ionic strength was greatly decreased by reduction and alkylation. The same treatment did not affect glutenin significantly. Configurational changes in gliadin may account for this difference.

In studies of model compounds, the rate of reaction at pH 8.3 of acrylonitrile with the sulfhydryl group of mercaptopropionic acid was 74 times

more rapid than the rate of its reaction with the amino group of β -alanine. Cyanoethylation of a mixture of these compounds resulted in complete reaction of SH groups accompanied by reaction of 10 percent of the NH_2 groups. Reoxidation in dilute solution of either reduced glutenin or gliadin gave a final product resembling the original gliadin. In concentrated solution, cohesive particles soluble only in urea-bisulfite solutions were obtained.

The research on cyanoethylation of sulfhydryl and amino groups is part of a broader study designed to throw light on the kinetics and other characteristics of reactions of vinyl compounds with selected chemical groups of amino acids found in wheat protein. These reactions are important to chemical modification of protein for industrial purposes. The information obtained in this study, as well as that resulting from characterization of individual protein components and from other basic research on composition and properties of wheat protein, is essential to the development of new products from either wheat protein, flour, or flour fractions.

In contract research at Armour Research Foundation, hydrolysis of gluten in formic, trichloroacetic or hydrochloric-acetic acid solutions yielded products shown by sedimentation to be nonuniform in molecular size. At Purdue University, contract research on desulfurization has been concerned with establishment of methodology and preliminary experimentation.

3. Synthetic polypeptides related to wheat gliadin. Modified gliadins soluble in water at neutral pH were prepared by grafting either polyalanyl or polyaspartyl side chains to the gliadin. The solubility of wheat gluten in water was enhanced considerably by grafting polyalanyl side chains to gluten. Significant progress was made in relating solution properties of polypeptides to their structure. This research is being conducted by the Weizmann Institute of Science, Rehovot, Israel, under a PL 480 grant.

B. Industrial Chemical Products

1. Acid-modified flour. Acid-modified flour (AMF) and hydroxyethylated acid-modified flour (HEAMF), prepared in the pilot plant of the Northern Division, were used in machine trials at the Forest Products Laboratory. Running characteristics of both were acceptable although protein enrichment of recycled size solutions of both materials took place. Improvements in paper properties effected by both experimental materials were similar to those effected by the control, which was a high-grade, commercial hypochlorite-oxidized starch. Despite variations in the paper sized with the control, AMF appears to be a satisfactory product although this conclusion cannot be drawn categorically. Demonstration of essential equivalence of HEAMF and the control appears to be definite.

Laboratory studies on AMF indicated that unextractable protein (either bound to starch or denatured) is the most likely cause of selective uptake of carbohydrate and accompanying lack of penetration when AMF is used as

a paper size. Brightness of clay coatings made with AMF or hydroxyethylated AMF had previously been reported to be significantly higher than for coatings made with commercial starch products. Observations of stored samples showed that this superiority has persisted for a 2-year period. Rheological properties and adhesive strength of the coatings equaled or exceeded controls.

Engineering studies on the process for producing AMF showed that satisfactory products can be made by using gaseous HCl, flour dried to 10 percent moisture, and a reaction time of about 3 hours. This gas-phase process is kinetically equivalent to that using dry flour and 4N aqueous HCl, and the products of the two procedures have chemically similar characteristics. Reaction time can be shortened to less than 30 minutes by operating at 110°F. Cost estimates indicate a cost-to-make of about 2 cents per pound exclusive of flour cost for the 4N HCl process. For the gas-phase process at higher temperatures, cost-to-make is reduced to about 1.5 cents per pound. Calculations assumed a plant making 12 million pounds of AMF annually.

2. Flour xanthates and xanthides. In addition to starch xanthates and xanthides (see Area No. 1, Part B-1), the analogous derivatives of wheat flour, bran, ground wheat and related materials produce advantageous improvement in properties when incorporated into pulp and paper products. A mixer-kneader is being used successfully for continuous production of cereal xanthates in the absence of inert diluents. Studies to establish conditions for optimum results are still in progress; however, present data show that for degrees of substitution in the range of 0.07 to 0.17, 87 to 80 percent, respectively, of the added carbon disulfide reacts to form xanthate with a residence time in the mixer of 2 minutes. Data from all runs were submitted to Biometrical Services for statistical analysis to obtain information on the effects of conditions in production of xanthates with the mixer-kneader. A continuous 6.5-hour "production run" of xanthate was accomplished successfully.

Insulating wall boards were prepared containing flour xanthate crosslinked and insolubilized with zinc. Boards containing 10 percent of flour zinc xanthate were lighter but stronger than commercial boards. The best experimental boards were 1-1/2 to 2-1/2 times as strong as commercial boards of similar density. Drainage time in preparation of the boards was significantly shortened. Industry has expressed much interest in this development.

Other studies are providing much new information on the chemistry of cereal xanthates. Some of the more important results include: (1) Discovery of conditions for xanthation by a method requiring no solvent; (2) improved techniques for crosslinking with zinc ion; and (3) demonstration with model compounds that the xanthate-xanthide redox system is apparently reversible in the presence of certain solvents and inorganic salts.

3. New copolymers from wheat starch. In contract research at Stanford Research Institute, new techniques have been developed whereby starch graft copolymers such as the following can be obtained: starch with up to 40 percent add-on of methyl methacrylate, graft density up to 1 branch/65 AGU; starch with up to 25 percent add-on of styrene, graft density up to 1 branch/52 or 100 AGU at same add-on; starch with about 16 percent add-on of butyl acrylate or 17 percent add-on of methyl acrylate, graft density for both about 1 branch/25 AGU. It was shown further that oil-in-water emulsion systems can be used effectively for grafting of styrene to starch. Insoluble acrylonitrile graft copolymers could be solubilized by partial hydrolysis of the CN groups, showing that these copolymers are not crosslinked as previously supposed.

The new and improved techniques for preparing these graft copolymers make it possible to prepare a wider variety of products and thus greatly enhance the opportunities for developing commercially useful materials. Studies have been initiated to evaluate graft copolymers for various applications in paper, such as wet-end additives, sizes, adhesives and flocculating agents.

4. Evaluation of wheat flour products for applications in the pulp and paper industry. Research on chemically modified wheat flour and related products is supported by evaluation studies to determine the quality and performance of these products in applications in the pulp, paper and paper-board industry. During the reporting period tests were conducted, for example, with wheat flour xanthates and xanthides, acid-modified flour, and wheat starch graft copolymers. Results of the evaluation studies are reported in conjunction with the general discussion of research on the specific wheat flour product.

5. Adhesives from gluten and dialdehyde starch (DAS). In contract research at Iowa State University, information is being developed on optimum conditions for the preparation and use of the gluten-DAS adhesive with regard to both workability and performance as an adhesive for wood and to the economy of adhesive production. Calcium hydroxide was the best solvent of seven systems studied for solid mixtures of DAS and gluten. Best strength of adhesive bond was obtained from a mixture of 40 parts of gluten with 2 parts DAS--800-900 p.s.i. Studies of aging the reactants, the reaction products, and the adhesive joints have been initiated to provide optimization of larger-scale studies.

C. Processing Technology

1. Fine grinding and air classification of wheat flours. Investigation of fine-grinding and air-classification properties of five flours from varieties of Oklahoma HRW wheat grown at seven fertilizer levels showed that individual variety and climatic conditions affected protein shift during fractionation of the flours to a greater extent than did variations

in fertilizer level. Softer varieties of HRW wheat responded better than harder varieties. Flours from three Michigan SWW wheats and three Indiana SRW wheats were successfully separated into low-protein fractions (below 3 percent) and high-protein fractions (over 20 percent). New Gaines wheat, a Pacific Northwest SWW wheat, responded better to air classification than Omar club wheat but not quite as well as Brevor SWW wheat.

Fractions from Bison and Pawnee HRW wheats were prepared, making a total of five varieties now being evaluated at the Western Division in baking tests. These varieties and the corresponding protein shifts resulting from fractionation are Bison, 60 percent; Pawnee, 36 percent; Triumph, 59 percent; Wichita, 50 percent; and Comanche, 39 percent. (Protein shift is defined as the percent of total nitrogen shifted into the high-protein fraction plus that shifted out of the low-protein fractions.) Sufficient quantities of fractions from the Michigan and Indiana wheats are now on hand to permit both baking evaluations at the Western Division and physical and chemical studies at the Northern Division.

Varietal differences appear to be the most significant factor influencing response of HRW wheat to fine grinding and air classification. Present results are representative of what can be expected until or unless basic investigation of the binding of endosperm starch and protein reveals new information that can lead to conditioning treatments capable of enhancing protein shift. Although it does not appear possible on the basis of present knowledge to obtain so-called industrial starch fractions from hard wheats, materials that can now be produced by fractionating HRW wheat flour may have definite advantages in baking and in certain industrial applications.

2. Wheat conditioning. Protein release, estimated microscopically, was evaluated in terms of temperature and moisture level during conditioning. Release appeared to improve as temperature increased and moisture decreased, with maximum release (6 percent) for wheat conditioned to 8 percent moisture at 70°. Good progress is being made in developing techniques for preparing specimens from wheat kernels for electron microscopic examination. Ultra-thin sections (200-500 Å) of aleurone cell walls and contents and of starchy endosperm tissue have been successfully prepared and examined. Wheat endosperm showed particles of undetermined nature embedded in the protein, but no special adhering layer around starch granules or between cell wall and protein could be noticed. Radial and inner tangential cell walls of aleurone cells were seen to be traversed by protein strands (plasmodesmata) which are absent in the outer tangential walls. Results of studies of the effects of conditioning of wheat on protein release, together with availability of practical techniques for use of the electron microscope, provide a basis for continued hope that means can eventually be found for improving the response of hard wheat flours to air classification.

3. Enzymes in malted wheat. In basic research conducted under contract by Kansas State University it was shown that earliest formation of α -amylase occurs near the embryo. The adverse effect of post-harvest dormancy on

malting of wheat appears to be due to the state of the embryo as well as to the presence of inhibitory substances in the seedcoat and/or endosperm. Formation or release of α -amylase in the endosperm was found to be stimulated by gibberellic acid and also by materials apparently coming from the germinating embryo. The effects of gibberellic acid seem to involve oxidative activity, since SH-blocking agents inhibited activation. Metabolic activity of the aleurone layer was also stimulated by gibberellic acid and by material from the embryo. Growth of the embryo appeared to be stimulated in turn by material from the endosperm or other parts of the seed.

4. Microbiology of flour. Research has been initiated on examination of the microflora of wheat, flour and flour products. The ultimate objective of the work is the development of methods and processes to reduce viable microorganisms in wheat flour as it is produced in the mill.

5. Quantitative measurement of wheat conditioning variables. In studies under a PL 480 grant at the Cereals Research Station, Research Association of British Flour Millers, St. Albans, England, effect of deep freezing, both continuous and intermittent, at high kernel moisture (25 percent) was investigated as a means of increasing endosperm fissuring. The treatments increased flour yield up to 4 percent without loss of color grade in Manitoba (hard) wheat. Preliminary treatments of this type on soft white U.S. wheats gave similar results with possibly a slight increase in protein release. Deep freezing increased endosperm fissuring, which might be regarded as a step toward increased protein release. However, the fissures do not occur selectively along the starch protein interface, as might be hoped, but rather between individual endosperm cells. Micro-wave heat treatment of wheat in which the temper moisture was concentrated in the bran resulted in deterioration, rather than in improvement, of milling quality.

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CORN, SORGHUM, AND OTHER FEED GRAINS
IMPROVED INDUSTRIAL, FEED AND FOOD PRODUCTS
Northern Utilization Research and Development Division, ARS

Problem. Abundant quantities of corn, sorghum, and other feed grains are now available beyond those amounts required to satisfy current needs. Both domestic consumption and export potential of these grains could be increased by development of new products for use by industry or of improved foods and feeds. Industrially, increased use of corn and sorghum will be mainly dependent upon increased markets for starch. However, flours derived from these grains are mixtures of starch, protein, and minor amounts of other components. Such mixtures have promise as raw materials for conversion to adhesives, water-soluble coatings, plastic materials, and related products that should have properties and uses different from related products derived from refined starch or wheat flour and that should contribute independently to increasing industrial markets. Isolated protein components of corn and sorghum flours should be suitable raw materials for production of useful resins and films. To achieve these utilization goals, more information is needed on basic physical and chemical properties and reactions of these flours, on the properties of component lipids, waxes, and proteins and their possible interactions with starch, and on the use of fine grinding and air classification and other new milling techniques for obtaining milled products having the most advantageous properties as industrial raw materials.

Because of the growing emphasis on increasing meat production, there is need for processes to obtain improved feed products such as high-protein feeds, mill feeds, feed concentrates, and feeds with high oil content. Such improvement could be achieved through research to obtain better knowledge of the biologically and nutritionally important constituents of corn, sorghum, and oats, to evaluate present, and to develop improved, milling and processing methods, and to ascertain the effects of such methods on the nutritional qualities of the products. In addition, because of the world shortage of protein in human nutrition, this research could enhance the export value of these grains by providing the necessary basis for development of high-protein and other food products that would be acceptable in foreign markets.

USDA PROGRAM

The Department has a continuing long-term program involving analytical and organic chemists, chemical engineers and structural biologists engaged in basic studies of the components of corn and sorghum and in application of the new knowledge gained to the development of improved processing technology leading to more effective utilization of these cereal grains.

The Federal scientific effort for research in this area totals 6.7 professional man-years. Of this number 4.4 are devoted to chemical composition and physical properties and 2.3 to processing technology.

Research on chemical composition and physical properties is conducted at Peoria, Illinois, and involves investigations of physiologically active nonprotein nitrogen substances in corn and of carotenoid pigments of corn, corn milling fractions, and yellow endosperm sorghum. A portion of the effort on carotenoid pigments is cooperative with Crops Research Division and is directed to development of corn and sorghum varieties having high carotenoid content. Such varieties are needed for improved food and feed products and to enhance the competitive position of U. S. corn in international trade.

Processing technology research, also conducted at Peoria, Illinois, involves pilot-plant studies of conditions and methods for increasing the yield of oil and grits by dry-milling processes. Effects of processing variations on industrially and biologically important components of corn are determined. During the reporting period research on dry milling of corn was redirected to emphasize studies on tempering, on improved processing of old or artificially dried corn, and on development of improved germination equipment.

The Department also sponsors research in this area conducted under grants of PL 480 funds to the following foreign institutions: Research Association of British Flour Millers, St. Albans, England, for studies of antioxidants occurring in oats (5 years, 1960-1965); National Institute of Agronomic Research, Paris, France, for basic studies of the physical chemical properties of corn zein (4 years, 1961-1965); Weizmann Institute of Science, Rehovot, Israel, for research on synthetic polypeptides with amino acid compositions related to zein and wheat gliadin (4 years, 1960-1964); and Indian Institute of Science, Bangalore, India, for research on separation of grain sorghum proteins (5 years, 1963-1968). These lines of work are under the subheading chemical composition and physical properties.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Nonprotein nitrogen substances of corn. New basic information has been obtained on the composition of corn and corn steep liquor. Quantitative estimation of heterocyclic nitrogen bases in corn steep liquor showed high levels of cytidine, uridine, xanthine, guanosine and adenine. Certain of these substances were not present in the original corn and others were present in steep liquor in larger amounts than anticipated from the composition of the original corn, indicating enzymatic degradation of nucleic acids and modification of bases during steeping.

Four previously unidentified amino acids found in corn extracts were characterized as homoserine, β -alanine, α -aminobutyric acid and α -amino-adipic acid. Comparison of different batches of corn steep liquor revealed significant differences in amino acid composition, especially arginine and ornithine. This type of information is potentially important to the processing and utilization of corn and derived products. For example, the kind and concentration of heterocyclic nitrogen bases may explain the stimulating effect of corn steep liquor on growth of microorganisms. Another possibility is that certain of these bases may be related to so-called unidentified growth factors said to occur in corn steep liquor.

2. Corn and sorghum carotenoids. Work was continued on investigations of carotenoid pigments in corn and sorghum to provide basic information needed in studies of the effects of processing on these biologically important constituents. Comparison of carotenoids in "normal-yellow" and "lemon-yellow" types of corn showed that the normal corn contained four times as much carotenoid pigment as did the other type and that α -carotene, β -carotene, zeinoxanthin and cryptoxanthin were present only in the normal corn. However, the lemon-yellow type contained five times as much zeta-carotene as did normal corn.

In cooperative research with Crops Research Division designed to assist in development of new varieties of corn and sorghum containing increased amounts of carotenoid pigments, some 450 hybrid corn samples were analyzed for xanthophylls and carotenes. Indications were obtained of the presence of gene modifiers in the white parent of yellow by white crosses.

Carotenoid analyses of nine new yellow-endosperm sorghum grains (protected from weathering) gave a range in carotenes from 0.3 to 1.6 ppm and xanthophylls from 2.7 to 10.0 ppm. These differences in the carotenoid levels of the yellow-endosperm sorghum grain samples are significant and indicate that several of the strains should be considered in future breeding programs.

3. Synthetic polypeptides related to corn zein protein. Good progress is being made in relating solution properties of polypeptides to their structure. For example, optical rotatory dispersion properties of helical polypeptides indicate that their unfolding by acids and bases is due to repulsion of electrically charged groups in side chains rather than to any effects of hydroxyl or hydrogen ions on hydrogen bonds in the α -helix. Synthetic work pertained to the wheat gliadin phase of this research, which is being conducted under a PL 480 grant at the Weizmann Institute of Science, Rehovot, Israel.

4. Properties of corn zein protein. At the National Institute of Agronomic Research, Paris, France, initial studies on commercial zein using column fractionation, rotatory dispersion, determination of molecular shape and weight by ultracentrifugation and light scattering, and amino acid composition have provided a foundation of techniques and information needed for

continuation of the research. The commercial zein showed a weight average molecular weight of about 35,000, and evidence was obtained that the molecule is relatively elongated. A new approach to protein fractionation was initiated using a column procedure with a gradient of both solvents and temperature. This work is being conducted under a PL 480 grant.

B. Processing Technology

1. Corn dry milling. Studies on milling of old corn showed that time and moisture level of tempering strongly influenced degerminator throughput and characteristics of the products. Best overall results were obtained with a 2-hour temper at moisture levels of 18-24 percent. Hot tempering decreased degerminator throughput. Other studies showed that for both 1960 and 1961 crop corns, vacuum tempering gave a higher throughput than did conventional tempering of equal time (2 hours). With a 0.4-hour vacuum temper a slightly better oil recovery was achieved. The improved hull release obtained with vacuum tempering of corn may reduce or eliminate the need for a second temper, thereby increasing the efficiency of commercial operations. In processing old corn, mills experience difficulty in obtaining adequate tempering and germ recovery. Vacuum tempering may prove advantageous in this operation.

A prototype brush-impact corn machine (designed and built at the Northern Division), when run as a dehuller, gave essentially whole dehulled kernels (12 percent had attached hulls) with no germ release. When the machine was run as a dehuller-degerminator the product was comparable to that produced by the Beall degerminator except that the grits had a higher oil content. Sorghum gave very good germ and hull release in the experimental degerminator. Horny and floury endosperm flours from six sorghum varieties resembled hard wheat flours in response to air classification. These results with corn and sorghum appear to point the way to significant improvement in dry milling technology.

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HIGH-AMYLOSE CORN - INDUSTRIAL UTILIZATION
Northern Utilization Research and Development Division, ARS

Problem. Varieties of corn have been achieved genetically that contain greatly increased amounts of amylose. Amylose, the linear fraction of starch, possesses film- and fiber-forming properties not available in ordinary starch which contains only about 27 percent of this component. Because the unique properties of amylose open areas of utilization closed to ordinary starch, the potential industrial value of this new crop is very high. Several problems must be solved, however, to realize this potential.

For high-amylose starch to have substantially improved properties as a raw material in comparison with ordinary starch, it should contain at least 80 percent of amylose. A few breeding samples have recently been observed that contain over 80 percent of amylose. However, only varieties containing 50 up to about 70 percent have so far been commercially available. Even at this amylose level, however, over 4 million pounds of high-amylose starch from first commercial plantings were utilized by industry in 1961. Although breeding is the task of the geneticist, utilization research is needed to provide information on amylose content, on changes in quantities and properties of the amylose, amylopectin, and other components such as oil and protein, and on milling characteristics of breeding samples in order to insure availability of satisfactory varieties.

A second problem is development of methods for economical isolation of pure amylose from high-amylose starch. For some anticipated uses, nearly pure amylose may be required for optimum properties. Although achievement of 80-percent high-amylose starch appears certain, it may not be possible to obtain much higher levels through breeding. Success in devising efficient fractionation methods will depend upon availability of adequate basic information on freeing and separating amylose from remaining starch components.

Finally, to insure utilization of the potentially large volume of high-amylose starch that could eventually become available, more information is needed on the chemical and physical properties of amylose and high-amylose starch and on methods for converting them economically to desired products. Success in this research could lead to an estimated consumption of over 600 million pounds of high-amylose starch by 1975 in films, fibers, plastics, coatings, and related products to which the linear character of amylose could make contributions.

USDA PROGRAM

The Department conducts a long-term, continuing program of research involving analytical, organic and physical chemists, structural biologists, and chemical and mechanical engineers who are engaged in basic and applied

research designed to increase knowledge of the properties and reactions of amylose and other components of high-amylose corn and to utilize this knowledge in development of attractive industrial applications for amylose and high-amylose starch.

The Federal scientific effort for research on utilization of high-amylose corn totals 19.3 professional man-years. Of this number 14.7 are devoted to chemical composition and physical properties and 4.6 to industrial utilization.

Research at Peoria, Illinois, on chemical composition and physical properties (14.5 professional man-years) involves study of amylose content of breeding samples, starch and starch granule composition, structure and properties; and composition and properties of proteins and other components of high-amylose corn. Studies on amylose content of breeding samples assist geneticists in developing varieties of high-amylose corn having increased amylose content. Cooperation with Field Crops Research Branch, Crops Research Division, is maintained in conducting these studies. A research contract (0.2 professional man-year) is in effect at Arizona State University, Tempe, Arizona, for basic research on the interaction of "V" amylose with small organic molecules. Research on industrial utilization, which is conducted at Peoria, Illinois, is devoted to studies on separation of amylose from high-amylose starch, and formation and properties of amylose films (4.6 professional man-years). Initial phases of research on amylose films were completed during the reporting period.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Amylose content of breeding samples. During the reporting period 15,867 samples of high-amylose corn were analyzed. These were supplied under Memoranda of Understanding by the Bear Hybrid Corn Company, by the Missouri Agricultural Experiment Station and by Crops Research Division at the Missouri Station. Of the samples analyzed in the last 6 months of the period, nearly 12 percent contained 75-80 percent amylose, thus increasing the number in this range from the previous total of 250 to a total of 1,132 to date. In addition, a total of 10 samples containing over 80 percent of amylose have now been found. The highest value was 81.3 percent. (In this report percentages of amylose refer to apparent values determined by iodine titration. True amylose content, measured by quantitative fractionation, averages about 80 percent of the apparent value.) These results indicate that the development of high-amylose corn is proceeding to the objective in a satisfactory manner. Reports indicate that moderate quantities of high-amylose starch containing 70 percent of amylose are now available commercially.

2. Properties of components of high-amylose starch. Studies on structure of amylose and amylopectin (from 52-70 percent high-amylose corn) show a number average chain length for amylose of 490 AGU. (The term AGU refers to the glucose units of which starch is composed.) Average branch length of amylopectin was 36-42 compared to 27 for that from ordinary corn starch. For the high-amylose corn amylopectin the length of the inner segment was about the same as that for ordinary amylopectin but the chain length of the external branches increased with increase of amylose in the starch. Improvements in techniques for separation and molecular weight determination gave increased values compared to those previously reported. Present results for weight average molecular weights are 470,000 for dent corn amylose and 380,000 for amylose from 70-percent high-amylose corn.

More complete studies on neutral solvent systems revealed that a mixture of lithium thiocyanate and guanidinium thiocyanate will completely dissolve high-amylose starch at room temperature. Discovery of effective neutral solvents for starch is an important advance because use of these solvents minimizes chemical changes in starch and thus permits more accurate determination of molecular weights and other significant properties.

Whereas iodine sorption indicates 25-27 percent of amylose in dent corn, ultracentrifugal schlieren patterns indicated 32-33 percent in the molecular weight range of amylose. The higher value was shown to be due to the presence of a low-molecular-weight (400,000) material having a degree of branching of 4.1 percent, a value similar to that of normal dent corn amylopectin. Discovery of a low-molecular-weight amylopectin-like component in starch is important from both the theoretical and practical points of view. Further study and characterization of this "anomalous component" in dent, high-amylose and other corns should contribute to our knowledge of the formation of starch and starch granules and increase our understanding of the chemical and physical properties of corn starches.

3. Proteins of high-amylose corn. Examination by starch gel electrophoresis of various protein fractions of waxy, normal dent and amylomaize hybrid corns (isogenic except for wx and ae genes in the waxy and amylose types) revealed no differences in number or relative amounts of components detected in the zein, globulin and glutelin fractions. Gel electrophoretic studies of reduced zein, globulin and glutelin preparations from normal dent corn showed that components in the reduced glutelin had counterparts in either the reduced zein or reduced globulin preparations. No components unique to the glutelin preparation were observed.

Gel filtration on Sephadex removed pigments from corn globulins but did not resolve individual globulin components. Chromatography on carboxymethyl- and DEAE-cellulose yielded fractions of much less complexity but again did not resolve individual components. An apparently homogeneous component was, however, obtained from the globulin fraction by a salt-precipitation technique.

These studies are providing basic information on corn proteins that will be applicable to the investigation and interpretation of variations in processing characteristics and to the detection of alterations of constituents by processing.

B. Industrial Utilization

1. Fractionation of high-amylose starch. In engineering research, a technically feasible process has been developed for recovery of amylose from high-amylose starch by complexing with selected fatty acids and alcohols. Application to commercial high-amylose starch (60 percent apparent amylose) gave good yields of amylose of 85- to 90-percent purity. Good separations could not be obtained using the commercial procedures presently employed for dent corn starch.

2. Amylose films. By extrusion of amylose dispersions at -16 to -19° C. into the eutectic mixture of ammonium sulfate, sodium sulfate and water, unsupported amylose film has been produced at speeds up to 400 feet per minute. The film loses strength, however, during subsequent washing prior to drying by conventional means. Use of nonaqueous media for washing may prove to be advantageous. For example, dehydrating wet, unwashed coagulated amylose film in glycerol gave a film having a wet tensile strength of 1,000 lbs. per sq. in. Evaluation of hand-cast films prepared by the alkali-dispersion method from a variety of amylose materials indicated that a minimum of 75 percent amylose is necessary for good film production; that amylose content was, within limits, more important than intrinsic viscosity; and that defatting was necessary to produce films with good forming, handling, and final properties.

PUBLICATIONS AND PATENTS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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WHEAT AND CORN - FERMENTATIVE CONVERSION TO NEW
INDUSTRIAL, FEED AND FOOD PRODUCTS
Northern Utilization Research and Development Division, ARS

Problem. By fermentation of cereal grain substrates, new products can be obtained that are not readily available by other means and have promising potential for industrial, agricultural, and food uses. Processes now under development, if brought to successful conclusion, could lead to increased consumption of an estimated 40 million bushels of grain for fermentative conversion to stable viscosity agents for secondary petroleum recovery by flooding of spent oil wells, to new organic acids and enzymes for industrial use, to feed supplements, and to effective biological insecticides and other pesticides that are harmless to man. In addition, there are good possibilities for utilizing fermentation processes to produce new food products that should promote foreign use of U. S. grains.

To accomplish these objectives and to realize the full potential of fermentative techniques for increasing utilization of grain, a broad program of exploratory research is required to find and identify through taxonomic studies species of organisms producing potentially valuable products, to isolate high-yielding strains or develop them by mutation, hybridization or genetic selection, and to develop basic information on culture media, special nutrients, and other factors required for optimum growth of microorganisms and maximum yields of desired products. Continued maintenance and expansion of a collection of pure cultures of well-characterized organisms is necessary for this research. For successful translation of laboratory results into commercially useful processes, more information is needed on new techniques of fermentation, on development of economical methods of growing organisms and handling fermentation processes on a large scale, and on special procedures for efficient isolation and purification of products from fermentative reaction mixtures. Finally, the most appropriate end uses for products must be identified and information obtained on product evaluation and development.

USDA PROGRAM

The Department has a long-range continuing program involving analytical and organic chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic research on microorganisms and microbiological reactions and products and in application of both known and newly discovered principles to the development of practical fermentation processes for conversion of cereal grain substrates to useful chemical, biological, feed and food products.

The Federal scientific effort in this area of research totals 55.3 professional man-years. Of this number 13.8 are devoted to basic research on fermentation processes; 21.3 to industrial chemicals; 15.3 to biological pesticides; and 4.9 to feed and food products.

Basic research on fermentation processes conducted at Peoria, Illinois, (13.8 professional man-years) includes study of taxonomy of molds, yeasts and bacteria; factors affecting viability of microorganisms; and microbiological reactions and products. Basic to these investigations and to the Division's entire research program on fermentation is assembly and maintenance in pure culture of a large collection of agriculturally and industrially important microorganisms. Much of the research on microbiological reactions and products is conducted by the Pioneering Laboratory for Microbiological Chemistry. During the reporting period exploratory research on microbial amination of unsaturated fatty acids was discontinued. Research on taxonomy of Pseudomonas is being held in abeyance to permit assignment of personnel to more urgent problems.

Research at Peoria, Illinois, on industrial chemicals (21.0 professional man-years) involves fermentative production of microbial gums, organic acids, and other products for use in the chemical industry. This work includes investigation and development of improved or new procedures for conducting industrial fermentations. A research contract (.3 professional man-year) with the University of Arizona provides for studies on polymerization of selected fermentation acids and derivatives of fatty acids.

Research at Peoria, Illinois, on biological pesticides (12.5 professional man-years) is devoted to studies on biological insecticides for Japanese beetle, other insect control agents and plant antibiotics. Investigations on biological insecticides for Japanese beetle and on other insect control agents is cooperative with Entomology Research Division and Plant Pest Control Division. Research on plant antibiotics involves cooperation with Crops Research Division. During the reporting period research on insect attractants was completed. Research contracts (2.8 professional man-years) covering various phases of research on Japanese beetle pathogens are in effect at Michigan State University, East Lansing, Michigan, for study of factors important to large-scale propagation of the pathogens (.5 professional man-year) and for basic research on enzyme activity in sporulation (.7 professional man-year); at Kansas State University, Manhattan, Kansas, for investigation of stabilization of vegetative cells of the pathogenic organisms (.5 professional man-year); at the University of Minnesota, St. Paul, Minnesota, for fundamental studies on the transfer of genetic determinants of sporulation from one microorganism to another (.5 professional man-year); and at the University of Illinois, Urbana, Illinois, for research on the applicability of a sporulation factor produced by bacteria to Japanese beetle pathogens (.6 professional man-year).

Research at Peoria, Illinois, on feed and food products (4.4 professional man-years) involves study of production of microbial carotenoids suitable for feed supplements and development of new fermented wheat foods that can help increase export markets for U. S. wheat. A research contract (.5 professional man-year) with Michigan State University, East Lansing, Michigan, concerns evaluation of biological availability of fermentative β -carotene when fed to poultry and swine.

The Department also sponsors research in the fermentation area conducted by foreign institutions under grants of PL 480 funds. Basic research on fermentation processes involves grants to the National Institute for Agronomic Research, Madrid, Spain, for collection of new species of yeast (5 years, 1960-1965); University of Helsinki, Finland, for basic studies on organic phosphorus compounds of yeast (5 years, 1960-1965); University of Milan, Italy, for basic studies on the metabolic pathway to 2-ketogluconic acid in Acetobacter species (4 years, 1960-1964); University of Allahabad, India, for collection of new Mucorales species (5 years, 1961-1965) and studies on survival of lyophilized microorganisms (5 years, 1962-1967); University of Durham, Newcastle-upon-Tyne, England, for investigations of sugar phosphate derivatives in molds (5 years, 1962-1967); and Indian Institute of Science, Bangalore, India, for basic research on enzyme systems involved in Pseudomonas conversion of glucose (5 years, 1962-1967). Research on industrial chemicals involves a grant to Superior Institute of Health, Rome, Italy, for studies on foaming in anaerobic fermentations (2 years, 1961-1963). Research on feed and food products involves a grant to the "Giuliana Ronzoni" Scientific Institute of Chemistry and Biochemistry, Milan, Italy, for research on production of vitamin B₁₃ (5 years, 1960-1965).

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Research on Fermentation Processes

1. ARS Culture Collection maintenance and service. As of January 1, 1963, the ARS Culture Collection contained 13,559 permanent cultures, an increase of 3,576 over 1962. During calendar year 1962, 2,497 cultures were distributed, 1,852 to domestic addresses and 645 to foreign countries.

In a recent search of the records, the Culture Collection reservoir was found to contain representatives of only 8 genera of Tuberculariaceae out of approximately 150 known genera in this family of Fungi Imperfecti. Most of the isolates belong in 3 genera, namely Fusarium, Epicoccum, and Myrothecium. Since this observation, 17 strains of 8 genera, including representatives of 4 genera new to the Collection, have been added. Of these, 3 isolates from fescue seemingly represent a new species of Lomachashaka, a monospecific genus reported only once in the literature. The monospecific genus Volutina has been reported only twice and the fungus was not obtained in pure culture in either case. We now have 2 cultures, one that we isolated and another that was sent to us by Wayne State University, Detroit. These presumably are the only pure cultures of these organisms in existence.

Recently, 8 isolates of Aspergillus flavus were received from the Commonwealth Mycological Institute (England). These strains have experimentally produced substances toxic to ducklings. They were isolated in England at the Central Veterinary Laboratories from peanuts and peanut meal from Nigeria, Uganda, and Brazil.

At the University of Allahabad, India, a large number of interesting and different forms of Mucorales have been isolated. These represent 52 different species including some new ones. All new and significant cultures are sent promptly for incorporation into the ARS Culture Collection. In studies on survival of lyophilized cultures, also in progress at the University of Allahabad, over 100 cultures of Aspergillus niger, Aspergillus terreus, etc., have been isolated. A number of morphological and biochemical characteristics are being determined for study with respect to alterations during repeated lyophilizations. These investigations are being performed under PL 480 grants.

2. Bacteria investigations. Emphasis was placed on antibiotic production by strains of one taxonomic group of Actinomycetes (produces streptomycin, rhodomycin, cycloheximide, etc.). Antibiotic spectra, cross-antagonism activities, and paper-chromatography patterns (using three solvent systems and five test organisms) afforded further information that can be used to determine how precisely cultural characteristics and antibiotic-producing capacity (qualitative) are related. This knowledge, when combined with the usual morphological data, will allow more objective characterization of strains and should aid in correcting current misinformation on taxonomy of streptomycetes.

Research on taxonomy of Pseudomonas is being held in abeyance to permit assignment of personnel to the Japanese beetle milky disease problem.

3. Yeast investigations. Studies on Chlamydozymaceae, a new family of yeasts, have resulted in discovery of a new type of sexuality and inheritance mechanism of extremely primitive character. A new species of Chlamydozyma was found to have hybridizing characteristics that will facilitate correct designation of the sexes of these yeasts.

A yeast responsible for a very persistent infection of cadavers that were injected with embalming fluid and stored in 4-percent phenol solution was sent to the Northern Division by a medical school for identification. The infection had resisted all available microbicides and was terminated only when the medical school occupied completely new quarters with different cadavers, new storage tanks and uncontaminated preservatives. The yeast was found to be a new species of Hansenula and to exist in two readily interchangeable types, one oxidative and one fermentative. The yeast has been named H. petersonii. A new theory according to which mutations regulate the most economical synthesis of enzymes for utilization of sugars or other metabolites is proposed on the basis of the fermentative-oxidative shift in H. petersonii.

4. Mold investigations. A cup fungus, Plectania occidentalis, has been found to produce on a glucose substrate yields as high as 35 percent of a new polysaccharide consisting of at least 90 percent of glucose units. No other sugar has been found, but traces of uronic acid have occasionally

been indicated. The same polymer is produced from either glucose or xylose as a substrate, but although starch, maltose and sucrose appear to be utilized, no polymer is formed with these substrates. Viscosity of solutions is not significantly affected by salts except borates nor by acid or alkali at moderate temperatures. Polymer solutions have been autoclaved for 2 hours in the presence of calcium chloride without change. The polymer is comparatively inert to microbial attack.

Production of a polysaccharide by a cup fungus is a phenomenon of unusual interest since it is believed that heretofore no product except cells was known to result from gross carbon turnover by a higher fungus. Both the fermentation and the polymer have characteristics indicating potential industrial value. In addition, this discovery raises several questions of fundamental scientific importance. For example, what is the mechanism whereby either the 6-carbon sugar glucose or the 5-carbon sugar xylose are converted to a glucose polymer but no polymer is produced from maltose, starch or sucrose even though these carbohydrates yield glucose on hydrolysis? What structural features of the polymer account for its properties in comparison with other fermentation polysaccharides? Answers to such questions would be significant contributions to basic science as well as provide knowledge that could be applied in our research program in several areas.

Taxonomic research on Mucorales revealed three varieties (two of which are new) of Rhopalomyces elegans, the microorganism that parasitizes eggs of the nematode genus Rhabditis. A new species of Absidia, named A. californica, was discovered. A surprising number of new taxa are being found in the several hundred isolates of Absidia examined. The sexual stage has been found in every species so far studied. More complete taxonomic information was attained on Absidia ramosa-corymbifera. This is undoubtedly the most common and economically important species of Absidia. It occurs in koji, stored grains, heating hay, curing tobacco and sewage. Its study completes work scheduled for the genus Absidia.

5. Microbiological processes and products. In the Pioneering Laboratory for Microbiological Chemistry, studies on the formation of D-arabitol by Saccharomyces mellis showed that the reduction in sugar alcohol production observed when phosphate is in the medium was caused by repression of the enzyme responsible for removal of phosphate from the intermediary product, D-ribulose-5-phosphate. Other steps in the conversion of glucose to D-arabitol were also elucidated. Evidence has been obtained that isolated cell particles from photosynthetic bacteria must undergo some physical change before becoming photochemically active in electron transport reactions. An active hydrogenase unaffected by the presence of light or calcium ion was shown to be present in cell-free extracts of Rhodospirillum rubrum.

Research on macromolecules responsible for agglutination of opposite mating types of the yeast Hansenula wingei resulted in isolation of a soluble factor from type 5 that has properties similar to living type 5 cells. Thus, the factor agglutinates cells of the opposite mating type 21, it is adsorbed from solution only by active mating type 21, and, like the parent type 5 cells, it is inactivated by agents that break disulfide bonds. This factor is therefore one, if not the only, specific agglutinating factor present on the surface of type 5 cells. Purification and characterization of the factor are in progress.

Research is continuing on the characterization of an extracellular lipid produced by H. ciferrii, on new aspects of fonsecin structure revealed by nuclear magnetic resonance, and on the metal-chelating properties of ramulosin. In the course of these chemical studies a new reagent, dicyclohexylethylamine, was found to give superior results in the small-scale formation of phenacyl and methyl esters of carboxylic acid. These esters are important derivatives that are widely used in characterization of organic compounds.

In research under a PL 480 grant at the University of Milan, Italy, stable cell-free preparations of Acetobacter have been developed that have activity in causing specific conversions expected to be part of the pathway from glucose to 5-ketogluconate. Of particular significance is the ability of the particulate fractions of cells to form 5-ketogluconate. The work should ultimately define the pathway and thereby provide a possible basis for control of fermentations done with whole cells.

At the University of Helsinki, Finland, the major nucleotide and sugar phosphate components of Torulopsis utilis were identified and separated by a rapid two dimensional paper chromatographic method. A short-term radioactive tracer labeling technique was developed, and preliminary metabolic turnover experiments were conducted. These techniques are being applied to the study of carbohydrate metabolism in yeast under various physiological conditions. This work is being performed under a PL 480 grant.

Studies on microbial sugars, their phosphate derivatives, and related compounds, which are conducted under a PL 480 grant by the University of Durham, Newcastle-upon-Tyne, England, have revealed that the polymers of Penicillium griseofulvum contain mannose, glucose and galactose as do other Penicillium organisms and that they also contain phosphates. Two of the polymers of Streptomyces niveus had a repeating unit of glucose and mannose, whereas a third had glucose, glucosamine and phosphate. The nucleotide fraction of the streptomycete is being studied in order to provide a better understanding of the biosynthesis of antibiotics and polysaccharides.

B. Industrial Chemicals

1. Conversion of grains to fermentation media. A laboratory process has been developed for enzymatic conversion of the starch in ground grains to glucose-containing sirups that are economical media for production of industrial chemicals and antibiotics by fermentation. The method, which is based on α -amylase and amyloglucosidase, is effective for ground sorghum, ground corn, corn flour and corn meal. Yields of glucose from sorghum and corn amount to 95 percent of theoretical. Solids remaining after enzymolysis of sorghum amounted to 23 percent and contained 4 percent nitrogen. About one-fifth of the nitrogen in the original sorghum was solubilized. For corn the residue was 26 percent and contained 3 percent nitrogen. About one-third of the nitrogen in the original corn was solubilized. Preliminary calculations indicate that on a sugar basis cost of the sirup from corn is probably less than that of molasses products. Enzymatic conversion of ground corn and sorghum and related materials to glucose sirups has elicited much interest from industry as evidenced by the large number of inquiries by letter, telephone, and personal visits by industrial representatives.

2. Enzymatic modification of wheat flour. Conditions for a two-step enzymatic conversion of wheat flour to a preparation that could be used as a surface size or coating for paper have been worked out using pepsin and bacterial subtilisin as the proteolytic enzymes and bacterial α -amylase as the amylolytic enzyme. The gluten can be degraded to either large or small molecular-weight fragments depending on the choice of proteolytic enzyme. Study of flour fractions containing 2 to 24 percent protein showed that those containing 2 to 5 percent required large amounts of amylase and long reaction times. The higher protein fractions required less amylase and time but yielded sizing material of lower quality. By treating a fraction containing 7 percent protein with amylase only, a product was obtained that compared favorably (as a tub size) with Super-film 40 (a superior commercial sizing starch). Production of an enzymatically converted flour fraction comparable, as a tub size for paper, to a leading commercial starch product is encouraging. The contrasting results with high and low protein flour fractions point up the necessity for evaluating the effects of enzymes originally present in the flour.

3. Fermentation acids. Engineering studies on fermentation of wheat starch slurry (from the batter process for production of wheat gluten) to citric acid, were continued with emphasis on scaling-up the process. As previously reported, the microorganism used for the fermentation consumes 75 to 80 percent of the starch of the medium. A similar result was obtained with a synthetic medium containing 10 percent glucose. Complete sugar utilization was achieved by addition of enough calcium carbonate to neutralize one-half of the anticipated citric acid yield. Yields of citric acid amounting to 65 percent by weight (based on glucose) have been achieved in 60-liter fermentors.

Specifications of the research contract with the University of Arizona provide for study of vinyl derivatives of fatty as well as fermentation acids. Under this contract, which is sponsored by all four utilization research laboratories, work related to the Northern Division commodities has so far dealt with vinyl derivatives of fatty acids. Studies on use of such derivatives as internal plasticizers for poly(vinyl chloride) show that both the plasticizing ability of the internal plasticizer as well as its influence on side-chain crystallinity are factors of major importance.

4. Studies on continuous fermentation techniques. Since the last report, one producer of B-1459 microbial polysaccharide has installed a commercial-size fermentor and is considering installation of two more. One company has reportedly made a 50,000-gallon run. There is active interest in the QAC (quaternary base) method for isolating the product and at least two companies are evaluating the economics of the process. At this critical stage in industrial development of B-1459 polymer, the importance of finding the most economical conditions for production cannot be overemphasized. The problem is being attacked by initiation of research on the use of continuous fermentation techniques and on simplification of the fermentation medium.

In the pilot plant, equipment has been modified for continuous fermentation and some preliminary testing has been completed. Laboratory studies on simplification of the medium showed that either soybean meal or "Fermatein" (a commercial cottonseed meal preparation) gave equal or better yields than distillers' solubles. Ash content of the product was reduced by lowering the concentration in the medium of phosphate buffer and magnesium sulfate. Soybean meal and Fermatein are cheaper than distillers' solids and indications are that only 40 to 50 percent as much of these less expensive materials would be required. However, further work is required to establish that their use does not change properties of the polymer or interfere with its recovery. For both conventional and continuous fermentation, a medium having all components in solution would be highly desirable.

5. Foaming in fermentations. Research under a PL 480 grant at the Superior Institute of Health, Rome, Italy, has shown that a relatively small dilution of a filamentous fermentation caused a large drop in viscosity and correspondingly large increase in aeration efficiency, thus indicating that excessive mycelial growth is perhaps deleterious in mold fermentations. As might be expected, bacterial fermentations were more efficient from the standpoint of oxygen absorbed. The results suggest that fermentation efficiency may well be increased by proper balance of cell growth and product formation with less expenditure for power to achieve necessary aeration.

C. Biological Pesticides

1. Biological insecticides for Japanese beetle. A maximum of 1-2 percent sporulation of a selected strain of Bacillus popilliae has been consistently achieved by 10 days incubation on a sugar-free solid (agar) medium containing yeast extract and acetate ion. Further work confirmed the absolute repressive effect of glucose and the necessity of acetate for sporulation. Efforts to increase rate and/or extent of spore formation and to obtain sporulation in liquid media have not yet been successful. A small number of these spore structures withstood heat shocking and survivors grew in vitro. They did not infect larvae, perhaps because of the small number of spores in the preparations. Several treatments have been found that increase germination of B. popilliae spores in vitro. The most infective available strains of B. popilliae and B. lentimorbus have been identified.

Nonvolatile acids found in hemolymph of Japanese beetle larvae include lactic, malic, succinic and glycolic acids. The presence of several others is indicated but not confirmed. Volatile acids found were acetic acid plus small amounts of butyric, propionic and formic acids.

One or more growth factors for Bacillus lentimorbus and B. popilliae have been found in tap water and agar. When grown in media containing either or both of these materials, B. lentimorbus withstands endless serial transfer whereas in their absence lyophilized cells survive only two transfers. Growth of B. popilliae is more rapid in media containing these materials. Preliminary experiments indicate that the growth factor or factors may be inorganic in nature. Polarographic measurement of oxygen in growing cultures of B. popilliae showed concentrations during the log phase of growth ranging from 10 to 30 percent of saturation levels.

At Michigan State University evidence has been obtained for metabolism of glucose by B. popilliae via the tricarboxylic acid cycle. Acetate is produced by growing cells and oxidized by resting cells; however, different strains of B. popilliae oxidize acetate at different stages of growth of the cultures. For example, one strain will not oxidize acetate in a culture 24 hours old, whereas another will oxidize acetate at 24 hours and not at 8 hours.

Much information pertinent to the problem of sporulating Japanese beetle pathogens is being accumulated. So far, however, a unifying principle that will explain the significance and relationships of the various observations and lead to solution of the problem has eluded investigators. The limited sporulation on a sugar-free solid medium containing acetate, the discovery of the growth-promoting effects of tap water and agar, and the variable utilization of acetate by different strains suggest that additional emphasis on nutritional requirements may prove fruitful.

2. Insect attractants. Research on screening for insect control agents has been completed. In all, a total of 810 cultures were grown on

grain-based media, and samples were shipped to collaborators in Entomology Research Division for evaluation at five locations. As a result of this decentralized operation and the varying activities of the collaborators, all tests could not be performed as originally planned. The most extensive evaluation of the cultures was as attractants for two species of fruit flies. Review of the tests with all of the collaborators failed to elicit indications that any of the cultures had merit for possible commercial application. Nevertheless, some cultures did perform better than the standards in field tests, and one collaborator said he was considering restudy of two cultures in field tests this summer with Drosophila spp., which are nuisance pests around fruit and berry plantings and processing plants. It is unfortunate that tests on a wider range of insects and for purposes other than attractants were impracticable. However, despite difficulties encountered and the failure to discover products with commercial potential, the results confirm that fermentation cultures do offer possibilities for insect control agents.

3. Plant antibiotics. Of approximately 500 streptomycetes screened to date via shaken-flask fermentations, 196 were found to show only moderate activity against fungi. Ultraviolet absorption studies were conducted with 170 of these and stability studies with 30. Seventy-seven of the 170 were nonpolyenic. Thus far seven strains producing stable and apparently new antifungal antibiotics have been detected.

D. Feed and Food Products

1. Microbial carotenoids. Continuing studies on fermentative production of β -carotene and other carotenoid pigments for use as animal feed supplements have resulted in discovery that dried mycelium of Blakeslea trispora from which carotene and lipid had been extracted is an effective replacement for β -ionone in the fermentation medium. When diphenyl amine is added to a β -carotene fermentation, this metabolic blocking agent causes reduced β -carotene synthesis and accumulation of an intermediate, phytofluene. It may be possible to convert this substance to lutein or zeaxanthin by treatment with other microorganisms. Xanthophyll pigments could be extracted only partially from cell pastes of Sarcina lutea and Micrococcus lysodeikticus. An alga (YB-3399) produced comparatively low concentrations of three xanthophyll compounds but no chlorophyll.

In engineering research, β -carotene has been produced successfully in a 30-gallon pilot-plant fermentation with the organism Blakeslea trispora. A practical recovery procedure for the mycelium, suitable for commercial application, was devised. Demonstration of successful pilot-plant production and recovery of β -carotene should assist in commercialization of the process. Although yields were lower than achieved in the laboratory, the results show that important engineering problems have been solved, and provide a sound basis for further process development.

Results of initial feeding tests at Michigan State University showed that fermentation β -carotene appeared to be as effective as vitamin A in promoting growth but somewhat less effective in replenishing the vitamin A stores of poultry and swine. Analyses performed at the Northern Division showed that there was some loss of β -carotene in the feed mixtures during the tests. Considerable difficulty was experienced in analyzing the comparison feeds, which contained low levels of vitamin A. Results of this first series of feeding tests should not be regarded as conclusive, since the influence of instability of β -carotene and vitamin A in the rations has not been clearly elucidated, in part because of these analytical difficulties. Also, the total data show a need for more rigorous control of preconditioning of test animals and of dosage with materials under test.

2. Vitamin B₁₃. In research under a PL 480 grant at the "Giuliana Ronzoni" Scientific Institute of Chemistry and Biochemistry, Milan, Italy, a method has been developed for extracting and purifying a potent growth factor for mice from distillers' solubles. Mevalonic acid is one of the components of the fraction and appears to be responsible for part of the activity of the factor. However, it is probably not the only active component. Evidence was obtained that orotic acid, thought by some workers to be part of the B₁₃ complex, was not a component of the factor. The present results may constitute the first demonstration that mevalonic acid promotes growth of the animal body.

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*Research supported by PL 480 funds.

WHEAT AND BARLEY - FOOD AND FEED PRODUCTS AND PROCESSING
Western Utilization Research and Development Division, ARS

Problem. In recent years huge stockpiles of wheat and barley have accumulated, depressing the agricultural economy through restricted grower incomes and expensive government control programs. The most promising solution lies in greatly expanded exports to meet the urgent food needs of large segments of the world's population and to secure an increased share of dollar markets for these grains. Knowledge and skills do not now exist to reach these goals. Ways must be found to adapt U.S. winter wheats and flours to the specific use requirements in Western Europe, a large potential dollar market. New food products from wheat must be created to fit specific needs and preferences of individual countries throughout the world. Simple, inexpensive methods must be devised for use in developing countries to process U.S. wheats into products appropriate for their socio-economic structures. Greatly expanded scientific knowledge of the composition and processing properties of wheat and barley is necessary. More complete knowledge of the chemical and physical properties of both the major and minor constituents of the grains, and of the changes that occur among them during processing, is needed to point the way to the new food and feed products and to new processing technologies. A thorough exploration must also be made of the inherent versatility of these grains as food and feed substances to achieve the utmost of their wide use potentialities.

USDA PROGRAM

The Western Utilization Research and Development Division conducts a broad program of basic and applied research on wheat and barley at Albany, California; under contract at Pullman, Washington; Lafayette, Indiana; Corvallis, Oregon; Kansas City, Missouri; Chicago, Illinois; and Manhattan, Kansas; and under P.L. 480 research grants in England, France, Poland, Italy, and Israel.

Basic studies are concerned with characterizing the soluble proteins (albumins and globulins), gluten proteins, lipoproteins and lipids in wheat and flour, identifying interactions in and between these substances, and characterizing the biologically-active compounds present in bran and germ. Different varieties and classes of wheat are being studied to determine intrinsic differences between the scarce high-quality bread-baking wheats and those surplus wheats which require chemical treatments or aging of flour for bread production. Applied research is being conducted on new and improved food and feed products and processes, with emphasis on the development of products to help fill the food deficit in overseas countries; microbial contaminants of flour and their elimination as a spoilage source for formulated foods; and on the extension of basic research findings to the improvement of manufacture of bread and other baked foods.

The Federal program of research in this area totals 46.1 professional man-years, including three scientists whose salaries are provided by two cooperators under Memoranda of Understanding (Farmers Co-Operative Commission Company - 2, and the Kansas Wheat Commission - 1), and eight contracts providing research at the rate of approximately 5.6 professional man-years per year. Of this number, 22.7 are assigned to investigations on chemical composition and physical properties; 21.7 on new and improved food products and processing technology; and 1.7 on new and improved feed products and processing technology. Research on emergency foods is conducted with funds transferred from the Department of Defense in an amount equivalent to approximately 2.0 professional man-years. In addition, the Division sponsors 13 research grants under P.L. 480 including 10 on basic studies and 3 on applications of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Protein Interactions. The value of wheat for bread-making depends upon the amount and quality of protein it contains. The production of a high-quality bread involves a working of the dough mixture to a proper degree, forming the loaf, and baking the bread. The mechanical development of a bread dough actually is a key to its utility. The work performed on a paste of flour and water transforms it into a smooth strong dough that is both elastic and flowing. To form a good loaf the dough must be elastic enough to retain its gas bubbles, but at the same time, must yield to the pressure of these bubbles to expand. For a product so common as bread, surprisingly little has been understood of the physical and chemical actions involved in the development of doughs for bread manufacture. Accordingly, our research is directed in part towards unraveling these mysteries.

The increase in protein solubility with mixing seems to offer an approach to understanding compositional influences on bread quality. Solubility increases as a result of breakdown of intermolecular cross-links and by molecular fragmentation. When enough of this occurs, the dough loses its strength and volume of baked bread is reduced. Factors that affect the rate and extent of protein solubility during mixing are now under intensive investigation. The mechanisms by which the desirable balance of elasticity and flow properties that are essential to the development of good loaf volume in bread doughs were found to involve the sulfhydryl and disulfide groups of wheat proteins. As doughs are mixed the protein solubility increases; the rate and extent of the increase can be influenced by chemical blocking of the sulfhydryl groups so they can not react. Chemicals that block the sulfhydryl groups were added at equivalent concentrations and a large and rapid increase in protein solubility was observed. When only half enough of the blocking material was added after a preliminary mixing of the dough ingredients, rather than adding it to the ingredients before mixing, the response was more rapid. The sulfhydryl

content had to be decreased to a critical level slightly below one-half the original content to give a large permanent increase in extractable protein.

2. Wheat Flour Dough Rheology. Basic studies toward relating flow characteristics (rheology) to the properties of wheat flour dough, are being conducted under Public Law 480 in the Rheological Laboratory of the Israel Institute of Technology at Haifa. Standardized testing of flour for bread making quality includes the use of equipment such as the Farinograph and the Extensograph. However useful this equipment is, their results have not provided unequivocal predictions of baking quality. Research under this project seeks to identify the basic mechanical parameters which change bread quality, and work out ways of measuring such parameters. A search of the literature was conducted, and exploration made into research conditions and techniques used to study the rheological properties of bread doughs. Equipment was installed, and, in some cases, re-designed to be more appropriate to the study of wheat flour doughs. In preliminary studies, measurement of dough sampled from the three characteristic stages of the Farinograph cycle is yielding information on typical high-quality wheat flour. Experimental conditions are being defined. For example, research must be limited to a very narrow temperature range if uniform results are to be obtained. Furthermore, partially-mixed dough will recover some of its original characteristics when allowed to rest and such rest periods may obscure data on rheological properties for the state of the dough being investigated. The characteristic softness of wheat flour dough has made it difficult to measure pieces of extruded dough in typical rheological measurements. Consequently, equipment is being modified. This investigation should improve our understanding of changes in the physical nature of dough during the mixing process.

3. Analysis and Characterization of Wheat Proteins. The differences between flours seem to depend in large part on proteins and their changes during the development of bread doughs. Consequently, refinement of measurement of types and kinds of protein constituents and changes of proteins during dough development are under intensive study. Pioneering research on immunochemical techniques is being carried out under P.L. 480 at the Pasteur Institute in Paris, France. The techniques of immunochemistry and gel electrophoresis were combined to give an exceptionally good analytical separation of proteins. The separated proteins are identified by the immunological reaction occurring when the antigenic protein combines with a specific antibody present in immune animal sera introduced into the gel. If any separated proteins are enzymes, their activity can be detected in the gel by means of specific color tests. Significant progress has been made in separating and identifying a number of wheat proteins and studies are in progress to relate the amounts and properties of these components to differences in baking properties of different varieties of wheat.

Results of this work are being applied without delay in the Department's research laboratory at Albany. Electrophoretic separations into bands of

protein constituents identified by immunochemical reactions can indicate the complexity of proteins in wheat flour. Polyacrylamide gel electrophoretograms have separated a larger number of components than were detected on agar gels in preliminary immunoelectrophoretic examination of flour extracts. Possibly some compounds separated by the former method have identical immunochemical response or may be polymers representing two or more separated components all having the same response. A procedure combining the resolving capacity of polyacrylamide or starch gels with favorable diffusion characteristics of agar gels has been developed and is being evaluated. Two-dimensional gel electrophoresis has also been undertaken to confirm the identity of component bands in one-dimensional separations. Research is planned in which individual proteins will be separated out and added back to bread doughs to determine their contribution to quality. Preliminary large-scale preparations, up to 35 to 40 grams of protein at a time, have been undertaken using column chromatography,

The development of quantitative measurements for specific proteins is being conducted under contract at Washington State University. A single extraction using aluminum lactate buffers at pH 3 has given the most satisfactory results to date. Such extraction followed by separation with disc electrophoresis appears to be a fruitful approach to quantitative determination of wheat flour proteins.

Another approach to investigating the chemical and physical properties of wheat gluten is being made by careful study of the alterations induced by ultrasonic vibration in research conducted under P.L. 480 at the Institut National de la Recherche Agronomique in Paris. At this stage of the research, it is not clear that reproducible controllable changes in gluten can be effected by the treatment. Further results and evaluations will be conducted, including investigations on gluten extracted from flour by different procedures. When and if controllable changes can be induced, other work will be undertaken to learn of the effects of treated gluten on bread making.

Research on solubility of wheat gluten proteins is being conducted under P.L. 480 at the Centre Nationale de la Recherche Scientifique in Montpellier, France. These studies, intended to provide knowledge of the foaming and surfactive properties of gluten proteins and of the means of increasing and decreasing solubility of these proteins in neutral solution, have been interrupted because of difficulties in obtaining equipment. No progress has been reported yet, and the grant has been extended for two years to enable the research group to complete the work.

In addition, basic research on nitrogenous compounds of wheat germ is being supported by a P.L. 480 grant at Universita di Bologna, in Italy. Data on protein and free amino acids confirmed previous published reports. Significant amounts of polyamines were found in wheat germ. Because polyamines can form complexes with nucleic acids and have physiological significance, they are currently of considerable scientific interest.

4. Chemical Basis for Cohesiveness in Gluten. Basic research on the properties of gluten which contribute to the usefulness of wheat flours in food and industry and to a greater understanding of how new applications may be devised is being conducted by contract with the Midwest Research Institute in Kansas City, Missouri. This project has just recently started. Stocks of crude gluten and purified gluten and glutenin have been prepared. Procedures for chemical modification, such as acetylation, esterification, breaking of disulfide bonds, and blocking of sulfhydryl groups, have been applied to gluten and some modified materials have been prepared. Analytical procedures for determining degree of modification also have been worked out. A procedure for rehydrating the protein specimens with good control of water content, pH, and salt content, and the preparation and mounting of rehydrated gluten strips in an Instron tester has been successfully conducted. Tensile strength, stress, and relaxation determinations will be made on the dehydrated protein strips. A statistical design for this research, covering selection of treatments and modifications of gluten samples, has been submitted and revised on the basis of comments from the subject matter specialist.

5. Enzymes in Wheat and Flour. Studies are under way to isolate and characterize amylase, proteinase, and lipoxidase enzymes known to occur in wheat and wheat flour. Enzymic action is involved in the modifications that take place during the mixing in development of bread doughs. It is also almost certainly involved in the maturation of wheat flours. A systematic study of the enzymes in wheat and the differences in activities of wheat samples may provide some helpful guidance for better means for converting hard red winter wheat into improved bread flour. Four distinct component bands, which have amylolytic activity, were separated by electrophoresis. The standard method for determining proteolytic activity in flours was shortened by several modifications in a new analytical procedure. Sulfhydryl blocking reagents caused a partial inhibition of the proteolytic enzymes and introduction of disulfide and sulfhydryl containing substances into the reaction did not restore the activity.

Studies of flour proteinase indicated that about 25% of the enzyme required a free sulfhydryl group to be reactive, whereas the remainder did not. Lipoxidase activity was found in water extracts from flour, but no activity has yet been found in fractions separated by ion exchange chromatography. Lipoxidase activity was completely lost by boiling the extracts, but sequestering reagents caused no diminution.

Basic studies on the relation of sulfhydryl groups to the amylolytic and proteolytic enzymes in wheat, flour, and malted wheat are being carried out under P.L. 480 at the University of Poznan in Poland. Research there confirmed the importance of maintaining the integrity of sulfhydryl groups in preserving the activity of amylolytic and proteolytic enzymes in wheat. Such enzyme activity is important, and supplemental additions of enzymes to flour are commonly made during milling and formulation of ingredients for

baking. Demonstration of the importance of sulfhydryl groups in preserving enzyme activity dictates establishment of processing conditions such that sulfhydryl groups will be undamaged.

Investigations were initiated on the coenzyme role of riboflavin of wheat endosperm at the College of Agriculture at Poznan, Poland under a P.L. 480 research grant. Preliminary work included development of standardized biometric procedures and separation procedures for wheat constituents important to the study.

In addition, studies of enzyme action in solid natural products particularly in relation to water contents in the range occurring in cereal grains, are being carried out under P.L. 480 at the Institut National de la Recherche Agronomique in Paris. Emphasis is on cereal lipases and studies involving kinetic investigations of enzyme activity. Synthetic substrate mixtures were prepared and dehydrated under conditions of minimum enzyme reaction and kept under well-defined conditions of water vapor pressure. Using isolated lipase from cereal sources, kinetic studies of enzyme activity are being conducted and reaction products will be isolated and characterized.

6. Flour Maturation. Investigations were initiated to develop methods for improving the baking performance of winter wheat flours without the use of chemical agents such as bromate, iodate, or chlorine dioxide and avoiding the expensive holding period for maturation. Preliminary stages of the work are underway. Baking tests were carried out to select suitable flour varying in response to oxidating maturing agents. The lipid components of these flour samples will be isolated and characterized. Comparisons in the composition of spring and winter wheat flour lipids were initiated. A contract has been negotiated to initiate research at Kansas State University at Manhattan, Kansas on qualitative and quantitative differences in the proteins and lipids of hard red spring and hard red winter wheat that account for the characteristically larger response of winter wheat to oxidative maturing agents. Spring wheat responds less to oxidative agents but performs well without treatment. Research in this area is needed to overcome the ignorance of why these wheat flours behave so differently.

7. Lipids and Lipoproteins. An understanding of the nature and function of gluten in wheat flour products requires fundamental information on the chemical and physical properties of their lipoproteins. These form a major class of constituents of gluten and exert an important influence on its properties. Lipid constituents of the lipoproteins of wheat were extracted and segregated into simple, glyco- and phospholipids. Composition of the separated constituents was ascertained by column, paper, and thin-layer chromatography and by other chemical analyses. Comparisons were made between lipid fractions from different types of wheat, and from wheat and wheat fractions that were treated in various ways. Appreciable differences occur in the ratios of glycolipids to phospholipids between flour and gluten and among air-classified flour fractions, depending in part on the protein content of the samples. Despite a general similarity between

the lipids of hard red spring and hard red winter wheat flours, a small but definite quantitative difference was observed. Hard red spring flours contained higher percentages of simple lipids than did the hard red winter flours. The compound lipids of hard red spring flour contained more lecithin and ester groups and less sugars than did the compound lipids of hard red winter flours. The association of lipids with proteins was found almost exclusively within the glutenin fraction of the proteins. Fractionation of gluten by several methods consistently resulted in concentration of lipid in the less soluble glutenin fraction. Lipid appears to prevent some chemical associations of proteins. When gluten lipids were extracted with water-saturated, normal butyl alcohol, the gluten exhibited decreased solubility in dilute acetic acid. A decrease in solubility appeared to reflect an increased association tendency among the glutenin components in the absence of lipid rather than an irreversible denaturation of the protein. Based on this information, more extensive evaluations of differences in flour lipid compositions and lipoprotein characteristics are planned. Selected lipid material will be prepared and compared with natural components by studying effects on dough properties. Although only a small amount of lipid material exists in wheat, it seems to have a very important effect on baking quality.

Work in this area is strengthened by two research grants under P.L. 480. A basic study of the composition of lipids of whole wheat has been undertaken at the Ecole Francaise de Meunerie in Paris, and another grant on studies of phosphorous compounds in flours at the Institut National de la Recherche Agronomique, also in Paris. Research in the first of these projects is concerned with evidence that certain types of fatty materials in wheat are important in determining the properties of flour and thus of a loaf of bread. Lipids undergo changes during preparation of the dough and during yeast fermentation. The results of these changes are being identified.

In the second project, extensive compositional studies have been conducted, comparing 10 United States wheats of different processing characteristics with three French grown wheats representing two of the general types of U.S. wheat. The relationship between total protein and sedimentation value of wheat seems to involve the amount of lipid available. The ratio of total protein to total lipid parallels the sedimentation value. The ratio of lipids left unextracted also seems to parallel the baking characteristics of the flour samples.

8. Bread Flavor. The importance of understanding the chemistry of bread flavor lies in the problem of preserving the aroma of freshly baked bread. By understanding what flavor is, and how to measure it, we start toward flavor enhancement and flavor stability. The exceedingly painstaking task of determining minute components of bread that create its delightful flavor involves development of elegant and sophisticated equipment and procedures to measure nerve-stimulating materials in fractions of a part per million.

The ingenuity demanded is matched or exceeded by that required for the second task of correlating compositional data with flavor and aroma responses. Organoleptic evaluations and correlation of subjective response to individual components will be emphasized. Eighty to 100 components of bread have been isolated and identified in volatile forms. These volatiles are extracted from cooked breads, or captured from the oven vapors while bread is being cooked. One fraction, which has a characteristic fresh bread flavor, was isolated from the oven volatiles. When exposed to air, it developed a typical stale aroma. A part of the investigation is directed to the volatile components produced in pre-ferments, such as are used in the continuous mix manufacture of bread. Nine different keto acids were found to occur in significant quantities in pre-ferments used for bread production. Tentative identity of these nine compounds has been made and analytical methods are being developed to measure them quantitatively in pre-ferments of various composition and history. With the knowledge being gained, each keto acid can be added in various amounts to pre-ferments under controlled conditions and its effect on flavor and aroma determined.

Related contract studies at Massachusetts Institute of Technology have been completed. In this contract research the effects were measured of modifying the composition of pre-ferment bread doughs on the volatile flavor and aroma components of breads baked therefrom. Taste panel comparisons were made of pre-ferment breads that had been prepared with additions of individual amino acids. Several of the amino acids produced significant changes in flavor and aroma. However, proline was the only additive which produced a bread preferred over controls. Quantitative comparisons were conducted on volatile materials collected from freshly baked samples of control bread and bread made with proline added to the pre-ferment. The addition of proline increased the total oxidizable material of the volatile concentrates. The increase in volatile concentrates was, within limits of measurement, accounted for by increase in ethyl alcohol in the volatile material collected. Concentrates prepared from volatile distillates of the control bread and proline containing bread were not found significantly different in chemical composition despite the organoleptic differences that had been found. Forty-one compounds were isolated from bread volatiles and 24 of these were identified, including 9 which had not been found in bread before.

There have been many significant advances in recent years in the chemistry of bread flavor and the tools of research have advanced so that progress should accelerate. However, there is still a long way to go before the chemistry of bread flavor is so well understood that we can adjust the ingredients and processes of bread-making to obtain products of superior flavor that are resistant to staling.

B. New and Improved Food Products and Processing Technology

1. Bulgur and Related Wheat Food Products. Bulgur, or parboiled wheat, has been continuously used as a diet staple since post-neolithic times in the Near Eastern cradle of civilization. Although not a substantial commercial item in the United States until a few years ago, bulgur is among the most important agricultural exports of the government donation program. In 1963 about 300 million pounds were shipped under Public Law 480. In a pilot program of the domestic school lunch distribution 800,000 pounds were used. Obviously as bulgur becomes more widely known, sales of wheat in this form will increase. A commercial venture in bulgur manufacture initiated during the past year, utilizes a process developed by the Department of Agriculture. This plant can produce 10 million pounds of bulgur per month and brings additional capacity to meet the rapidly growing demand for this product. The Department-developed process involves continuous conditioning and cooking at atmospheric pressures. The process uses either red winter wheat or white club. Bulgur obtained from both wheats was highly satisfactory judged by milling yield, organoleptic quality, and nutrient content.

Several canned bulgur products were produced in 150 to 200 can lots to evaluate formulations and processing, and to provide supplies for demonstration purposes. Cracked and whole kernel bulgur generally performed more satisfactorily than peeled raw wheat in canned products, but slight changes in formulation were necessary in replacing the raw wheat with the bulgur. Preliminary trials with rotating or tumbling pressure retorts indicate that it will be feasible to fill cans with the dry materials and blend the ingredients by agitation during processing. Products made this way were more uniform than mixed products cooked in a still pressure retort.

Quick-cooking bulgur was developed that provides for a wide variety of instant consumer products from wheat. Hot air puffing of whole kernel bulgur transforms it to crisp, expanded structures, which quickly absorb hot liquids so formulations can be made that are ready-to-serve in a matter of minutes. Instant soup, salad, desserts, and other mixtures were made to demonstrate the puffed bulgur.

A wide variety of attractive and nutritional wheat foods has been developed and recipes prepared and widely distributed. Demonstrations of many of these foods have been made to interested associations of wheat growers and professional and social organizations. Assistance has been given in the development of recipes suitable for the use of bulgur in the school lunch program.

2. Food from Wheat Fractions. New canned and dehydrated high-protein food products that utilize wheat are being investigated. Studies include work on technology to modify structural and textural properties of products made

from flour with and without protein fortification. The unique properties of starch components of wheat may be developed to make desirable textural changes. Protein-rich fractions obtained by air classification of flour and from mill feed fractions, are being looked to in the formulation and development of more nutritious products. Canned products using gluten as a binder, which are flavored and treated to suggest poultry, fish, and beef, have been produced in preliminary work.

Acid hydrolytic deamidation of gluten to improve wheat protein dispersibility in water and buffered solutions was demonstrated in contract work at Purdue University, Lafayette, Indiana. A product completely dispersible in a dilute phosphate buffer was produced by treatment of gluten with dilute hydrochloric acid. Twenty percent of the amide nitrogen was split from the protein and some peptide bonds were also hydrolyzed. Phosphoric acid hydrolysis may prove to be more effective and studies are being extended to air-classified high-protein flour fractions as well as gluten. Preliminary work shows promise in the development of powdered formulations of wheat that contain minerals and vitamins and would be usable as a food supplement in milk-short areas of the world.

3. Emergency Food Supply. Investigations of foods suitable for fallout shelters are being conducted with funds transferred to Agriculture by the Department of Defense. Two lines of research are involved: (1) on the bulgur wheat wafer previously conceived by the Western Utilization Research and Development Division for stockpiling in fallout shelters, and (2) on development of adjuncts for use with the bulgur wheat wafer. Close cooperation was given by Department scientists to the Office of Civil Defense of the Department of Defense and the Van Brode Milling Company of Massachusetts in connection with a half million pound trial procurement of the bulgur type shelter wafer.

Stability of bulgur wafers is being investigated in a five-year storage test recently initiated by a research and service contract with Oregon State University in Corvallis. Variables in the study include red and white wheat as the basic material, malt and corn syrup, nitrogen vs. air pack, storage at 40, 70, and 100° F.

Study of alternate methods for preparing expanded wheat is in progress. Heat-puffing steamed wheat without the normal bulgur preparation did not provide enough expansion of the individual kernels to produce a satisfactory wheat wafer. A cereal puffing gun has been installed for further studies. Hot fat puffing of debranned raw wheat was explored. Debranned white wheat of different moisture levels was treated in hot fat over a wide range of temperatures. Oil-puffed wheat had a pleasant toasted flavor but the puff indices indicate that further improvement would be necessary for good texture in the final wafer.

Efforts have been directed towards quicker evaluation of storage stability. Irradiation of ground puffed bulgur with ultraviolet light has been found

extremely effective in accelerating the changes measured by gas-liquid chromatographic patterns. If the hexanal produced is used as an indication of change, samples of ground puffed bulgur exposed to ultraviolet light in air showed increases of about 25-fold in eight days, 50-fold in nine days, and 75-fold in ten days. Exposure in oxygen in the dark, showed only a 3- to 4-fold increase in ten days.

Wafers have been made with substances reported to protect against radiation or radioactive fallout. Calcium carbonate, tribasic calcium phosphate, ascorbic acid, L-cysteine hydrochloride, potassium iodide, yeast, folic acid, methionine, and sodium calcium citrate have been added and the levels determined at which there is no adverse effect on flavor, texture, or general appearance. Should such additions be indicated, the quality of the wafer would not be affected. Possible influence of these additives on wafer stability is yet to be discovered.

Foods that would be useful with emergency supplies of bulgur wafer were selected for extended storage tests. Such tests were initiated by a second contract with the Oregon State University at Corvallis.

Considerable success has been achieved with cold water gels as food adjuncts for bulgur wafers. Further improvement in the clarity, flavor, and ease of mixing is being sought. Such products could be stored dry for stability, mixed with cold water, and used as flavored spreads for the wafer to provide variety. Investigations have been undertaken also on a highly stable fat spread resembling margarine that could be used with the wafer. Preliminary work is well under way on a different package for dry mixes which may be reconstituted with cold water (e.g., spreads, cold water gels, and icings). The dry mix would be packaged in an oversized plastic bag within a tin can. The bag can be removed from the can, cold water added, and mixing effected by kneading the bag. The adjunct could be extruded from the bag through a hole produced by cutting off a specially designed tip. Adjuncts packaged this way would require no equipment for preparation and would go directly onto the wafers.

4. Baking Quality. Baking quality of wheat flour, as related to compositional factors, is under continuing investigation. Air-classified fractions are now available over a wide range of protein content from five hard red winter wheat varieties. Bread baking and physical mixing tests of dough are in progress to study relationships of protein quantity and quality to baking quality. Unclassified flours are being sought which are similar in protein content to the various air-classified fractions. These natural flours will also be evaluated for baking quality to see if results obtained are the same as those in the separated fractions.

The effects upon baking of variation in wheat flour lipids are being investigated under P.L. 480 at the British Baking Industries Research Association in Chorleywood, England. Representative samples of U.S. grown wheat

are being analyzed for fat, evaluated for baking quality, and studied with formula modifications to determine the role of fat in bread loaves. Because varietal and cultural factors influence quality of samples, several years of investigation must be evaluated before conclusions can be drawn. However, even at this stage in the research, evidence is accumulating that certain fats are indeed important to the behavior of dough, the loaf volume, and crumb firmness of bread.

Continuous-mix bread manufacture has brought up a new problem in making bread doughs. Some flours tolerate nonfat dried milk to a greater extent than others. Research was initiated to study what components in flour limit the use of nonfat dried milk in continuous-mix bread manufacture. Tolerant and non-tolerant flours were selected for this study, and research was initiated to determine the relationships between milk solids and individual components of these flours. By cooperation with the Eastern Utilization Research Division, milk solids that have been treated in various ways are available for dough formulas to study their effects on baking quality. Specific changes occurring in the flour during mixing and baking will be examined. The objective is to develop methods for selection of flours with high tolerance, to determine milk treatments which will overcome the shortcoming, and to develop variations in baking procedures that will permit the usual amounts of milk solids in bread formulas.

5. Nutritive Value of Processed Wheat. The application of heat during the manufacture of bulgur and other wheat products, raises the question of nutrient retention. However, vitamin losses were found minimal for a range of conditions representing commercial operations. Preliminary chick growth experiments indicate that biological protein values are as good as or better than those of flour made from the same wheat. Leaching of protein from the bran into the endosperm may make amino acids more available. The nutrient quality of bulgur is approximately that of whole wheat flour, with thiamine losses less than 15%. Thiamine losses during the canning of wheat and the puffing of bulgur were significant, and the puffing operation somewhat impaired biological protein value. The processed products are nevertheless fair to good sources of several B-vitamins, including thiamine. The losses do not exceed the losses that occur in toasting and cooking of many common wheat products.

Studies aimed at rapid chemical methods for assay of nutritive value of proteins during processing of wheat products are being conducted under P.L. 480 at Cambridge University in England. Compositional studies relate the effects of heat to amount of lysine, methionine, and leucine in wheat products. This information is being related to the biological value of proteins containing these amino acids. These studies correlate data from rapid chemical analyses with those from the time-consuming animal assays. If these chemical tests correlate adequately with nutritive value, it will be possible to monitor industrial processes used in the production of wheat food products.

6. Elimination of Microbial Contamination of Wheat Flour. The recent growth of convenience foods, such as frozen and canned products and pre-mixes with flour, has brought attention to micro-organisms that frequently contaminate flour but that are adequately controlled when flour is used in commercial bread or other bakery products. Sanitation requirements are becoming more stringent in frozen foods, baby foods, and other products and have caused food manufacturers to limit wheat flour in many products. Refined starch, purified vegetable gums, and other thickeners are used in place of wheat flours for better sanitary control. Contract research at the American Institute of Baking in Chicago has been negotiated to determine the nature and extent of contamination that would be detrimental to flavor, quality, and safety of foods containing flour and to develop methods to eliminate contamination from flour during processing. Future research will include studies on the viability of organisms in flour for various uses and the effects of processes to reduce microbial contaminations to a negligible level. Research on this contract will begin in the very near future.

C. New and Improved Feeds and Feed Processing Technology

1. Improved Feeds from Wheat and Wheat Fractions. Research on feed utilization of wheat has been limited during the period of this report by unavailability of personnel. Chick feeding tests were conducted to determine the effects of bulgur processing on the nutritive value of wheat. Studies were made of both hard red wheat and Northwest club wheat. The bulgur process does not reduce lysine availability. Research in this area will develop toward new feeds based on the high-protein wheat milling byproducts. These materials contain higher levels of protein than the flour or the whole of the starting grain. Furthermore, the middlings, shorts, and other parts of the mill run have protein that is of greater biological value than that in the flour. Representative samples of mill run will be separated and fractions characterized for amount and biological quality of protein. Wet and dry separation and combinations thereof will be used to prepare protein-rich fractions, which because of concentration and biological value, would be useful to the feed mixing industry.

Contract research on estrogens in wheat bran and germ conducted at Iowa State University, Ames, has been concluded. Oils from wheat bran and germ were fractionated. Various fractions were assayed biometrically for estrogen-like activity. Such activity had been previously reported in the hydrocarbon fraction and was confirmed. Another fraction appeared, in preliminary bioassay procedures, to be of higher activity than the mixed hydrocarbons and obtainable in good yield. Research concentrated on this apparently homogeneous phenolic substance. On detailed study, it was found to be a homologous mixture of five compounds varying slightly in the number of carbon atoms on the side chain of an alkyl-dihydroxy benzene. Subsequent bioassay of the purified components did not bear out the original finding of estrogenic activity. It must be assumed that impurities not yet revealed but removed in the purification were responsible.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Chemical Composition and Physical Properties

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FORAGES AND FEED - PROCESSING AND PRODUCTS
Northern Utilization Research and Development Division, ARS

Problem. Fresh forage crops are the richest natural sources of a wide variety of nutrients essential to farm animals. The bulk of these crops, however, is preserved by such inefficient processes (hay making and ensiling) that 10 to 50 percent of the original dry weight and much larger amounts of certain valuable nutrients and growth-promoting factors are lost before the animal consumes the products. Dehydration is currently the only practical means for preserving a high percentage of the value of forage crops. Poultry and swine producers, aware of the value of dehydrated forage in feeds, nevertheless restrict the use of this product because of its high fiber and growth-inhibitor content. The livestock producer needs, and therefore the forage dehydrator needs to produce, feed ingredients from forages tailored to specific classes of farm animals. Intensive basic and applied utilization research are needed to develop new methods for processing forages to produce: (1) high-value, fiber-free juice or low-fiber products for nonruminant animals; (2) low-cost products, rich in fiber treated to make it highly digestible, for ruminants; and (3) a growth-stimulating supplement for ruminants, taking advantage of the presence in forages of such growth-promoting compounds as the recently discovered coumestrol. Forage products for ruminant feeding would be specifically designed for the mechanized feeding operations which will be essential for the 45-percent increase in livestock production to meet the projected 1975 requirements. Development of new processes and improved forage products would stimulate the production of large tonnages of forages as cash crops on high-value land now being used for crops currently in surplus.

USDA PROGRAM

The major part of the Department's research program on forages is maintained at the Western Utilization Research and Development Division, Albany, California. At the Northern Division, Peoria, Illinois, the Department has a short-term program involving one organic chemist engaged in research to isolate and identify the toxic component(s) of tall fescue grass responsible for a cattle disease known as "fescue foot." This research is cooperative with the Kentucky State Experiment Station which furnishes toxic and nontoxic fescue grass for chemical study and conducts bioassays of fractions and components isolated from fescue at the Northern Division. Liaison is maintained with the fescue breeding program of the Field Crops Research Branch, ARS, through the Agronomy Department of the University of Kentucky and with the Department's Pharmacology Laboratory at Albany, California.

The Federal program at Peoria, Illinois, totals 1.0 professional man-year, all of which is devoted to chemical composition and physical properties.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Fescue toxicity. Tests at Kentucky AES with their new bioassay technique indicated toxicity for crude alkaloids, aqueous residue and solids from the hexane-water interface encountered in extraction of lipids. The lipid fraction was considered nontoxic. These results contradict previous reports that only the aqueous residue showed toxicity. Evidently much additional work will be needed to standardize and to interpret properly data furnished by the new bioassay technique. It is quite possible that fescue alkaloids will prove to be implicated to a greater extent in toxicity than the earlier, cruder bioassay procedure indicated. About 0.5 ton of tall fescue hay was extracted with 80-percent ethanol. The extract was concentrated and shipped to Kentucky AES for further study.

A fraction believed to contain alkaloidal amine oxides was isolated from the aqueous residue obtained in conventional isolation of crude alkaloids. This fraction amounts to 0.17 percent of the hay or about twice the amount of the crude alkaloid fraction. Alkaloidal amine oxides have not been previously isolated from fescue. Such compounds from other plants have been reported to be toxic. It is significant that they occur in a fraction previously associated with toxicity of fescue.

PUBLICATIONS AND PATENTS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Chemical Composition and Physical Properties

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FORAGES AND FEED - PROCESSING AND PRODUCTS
Western Utilization Research and Development Division, ARS

Problem. The demand for livestock in the United States will increase 45% by 1975. Fresh forage crops are the richest natural source of many nutrients for farm animals. The bulk of forages, however, is preserved so inefficiently by haymaking and ensiling that 10 to 50% of the dry weight, and much larger fractions of the most valuable nutrients, are lost before the animals eat them. Dehydration is now the only practical means of preserving the high nutritional value. Poultry and swine producers are aware of the value of dehydrated forage, but restrict their consumption because of high fiber and growth-inhibitor content. The livestock breeder needs forage products tailored to specific animals, and the forage producer must adapt to his needs to sell.

Basic and applied utilization research are necessary to produce: (1) nutritional juice and low-fiber feed for non-ruminant animals; (2) fiber products which have been cheaply treated to make them easily digestible for ruminants; (3) growth stimulating supplements for ruminants based on the biologically active fiber digestion factor, and growth-promoting factor in forage. Further, new products should be adaptable to mechanical feeding. Improved handling will encourage farmers to put high value land now producing surplus crops into forages.

USDA PROGRAM

Current research in the Western Utilization Research and Development Division includes both basic and applied studies on forages, principally alfalfa and other legumes. The research is conducted at the Division headquarters at Albany, California, under contract at Berkeley, California, and under the P.L. 480 grant program in Edinburgh, Scotland. Basic compositional studies deal with the potent estrogen coumestrol (discovered by Department scientists), and other phenolic compounds present in forage legumes. The value of coumestrol-rich alfalfa as a growth stimulant for ruminants is being studied with financial support of the American Dehydrators Association. Also under study are other biologically active forage constituents, such as the chick growth-promoting factor in forage juices and alfalfa saponins which depress chick growth, and the mechanism of action of forage antioxidants. Processing of forages by "wet" (juicing) and "dry" (turbomilling and air classification) methods is being investigated.

The Federal program of research in this area totals 14.2 professional man-years, including 2.0 scientists whose salaries are provided by the Department of Agriculture and Inspection, State of Nebraska, and contract research equivalent to 0.5 professional man-years per year. Of this number 6.5 are assigned to chemical composition and physical properties; and 7.7

to new and improved feeds and processing technology. In addition the Division sponsors, under P.L. 480, a research project on forage composition.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Phenolic Constituents of Forages. Alfalfa and ladino clover are being extracted to isolate groups of compounds and individual compounds that exhibit biological activity. (See paragraph 2.) Chemical identifications are made and sufficient quantities of active compounds are obtained to be used in feeding studies. Under a service contract, 45 tons of alfalfa were extracted with acetone. From the extract, 1000 grams of purified coumestrol were obtained. The residue was further studied and separated by countercurrent distribution. Twelve components exhibiting intense fluorescence under ultraviolet light were isolated. These substances will be further characterized in forthcoming studies. Preliminary findings indicate that they are phenolic and some are structurally similar to coumestrol. Biological activity will be measured to discover whether or not some of these components may contribute to the occasional unexplained growth in alfalfa-fed animals.

2. Pharmacological Research on Forages. Biological activity of alfalfa and clover is determined by assay with laboratory animals. Pharmacological tests are made on concentrates, extracts, and fractions. Much attention has been devoted to coumestrol from alfalfa, which exhibits estrogenic activity in mice. Recently, several samples of alfalfa have contained coumestrol up to 200 to 500 p.p.m. with which it is possible to measure the activity of the alfalfa meal rather than an extract. Unexpectedly, when these alfalfa meals were fed to mice, the calculated estrogenic response based on chemical assays was not realized. However, if the acetone extract of the meal, which also contains coumestrol, is fed to the mice, there is a three-fold increase in uterine weight indicating estrogenic activity. Possibly an estrogen inhibitor may be a natural component of the alfalfa meal. In Australian research the isoflavone formononetin was found to exhibit considerable estrogenic potency in sheep. This plant estrogen, when assayed in mice, indicated a relatively low biological activity. A re-evaluation of the mouse assay as a criterion of potency in ruminants must be initiated.

3. Interaction of Forage Antioxidants. A new contract was made with the University of California, Berkeley, to follow leads uncovered under a previous contract. Lipids from alfalfa will be studied, and the chemical effects of processing and antioxidants on lipid oxidation will be elucidated. The investigation will be directed toward separating and characterizing lipid components of alfalfa, identifying changes that occur in them as a result of dehydration and storage, and determining the effects of various antioxidants and the chemical mechanisms by which their effectiveness is accomplished.

4. Structure of Alfalfa Polysaccharides. A structural analysis of alfalfa polysaccharides is being conducted under Public Law 480 funds at the Edinburgh University, Scotland. Research has been initiated along two lines. An examination of the polysaccharide components of alfalfa has been started with extraction procedures designed to obtain individual polysaccharide fractions for further identification and study. Secondly, a survey of the enzyme carbohydrase activity of extracts of dormant and germinating alfalfa seeds, stems, and leaves, has been initiated. Preliminary experiments gave evidence of several enzymes that are active on polysaccharide substrates. Large-scale preparations of these enzymes will be made.

5. Organic Acids. A study on the organic acids in alfalfa was initiated in cooperation with the Kellogg Foundation, whose grant program enabled an English biochemist, J. M. A. Tilley, to conduct research at Albany, California. Special chromatographic apparatus was obtained and details of methodology have been worked out appropriate to alfalfa. A Department scientist will continue independent study of the organic acids in forages based on the preliminary findings of Dr. Tilley.

B. New and Improved Feeds and Processing Technologies

1. Coumestrol-Enriched Feeds. Large cooperative animal feeding trials have continued into the third year using high- and low-coumestrol dehydrated alfalfa, screened from production lots at commercial dehydrating plants. Alfalfa meal for these studies has been obtained with financial help from the American Dehydrators Association. After three seasons, sheep feeding experiments at Oregon State University using alfalfa that is rich in coumestrol have indicated a 20% increase in gain and the production of meat. Meat quality has been judged superior to that from controls. Similar tests with beef steers did not show positive results at the coumestrol levels involved. Samples of coumestrol extracted by acetone from alfalfa have been sent to the Animal Husbandry Research Division for cooperative studies on protein balance in cattle, and to the Oregon and Indiana Experiment Stations for cooperative studies on lamb and steer growth.

2. Improved Alfalfa Meal. Alfalfa meal is being divided into low- and high-fiber products to provide specific components for mixed feeds. This research is supported in part by the State of Nebraska, Department of Agriculture and Inspection, which provides the salaries of two professional employees. Air-classification of fine-ground alfalfa was not effective. A more promising approach involves separation of leaf from grit and stemmy portions and then fine grinding and air-classification of the leaf fraction. Alfalfa containing 26% protein and 17% fiber has been separated into two components, one of which contains 29% protein and the other 30% fiber. Research on the composition of the alfalfa plant indicates 30% to 40% protein in clean leaf fractions and 40% to 50% fiber in pure stem fractions. Therefore, some further enrichment appears possible if more refined separation procedures can be developed.

Stability of dehydrated alfalfa has been improved by the antioxidant ethoxyquin, as reported previously. A substantial export market for ethoxyquin-treated dehydrated alfalfa has been developed. The long hot shipment overseas of alfalfa meal requires a more stable product than untreated alfalfa meal. Without an antioxidant, alfalfa meal imported into Japan and western Europe would have little of its specific nutrient value. Recently the Food and Drug Administration has set a tolerance of 5 p.p.m. for residues of feed additive ethoxyquin in or on the uncooked fat of meat from animals, except poultry, and a tolerance of a half a part per million for residues of the additive in or on uncooked muscle meat.

PUBLICATIONS AND PATENT REPORTING RESULTS
OF USDA AND COOPERATIVE RESEARCH

Chemical Composition and Physical Properties

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New and Improved Feeds and Processing Technology

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RICE - PROCESSING AND PRODUCTS
Western Utilization Research and Development Division, ARS

Problem. The productive capacity of U.S. rice growers has increased faster than domestic and export consumption over the past decade, limiting the income potential of this major world food grain. Detailed knowledge of chemical composition and physical properties, as related to processing, is needed to guide milling, processing, and product development of U.S. rices so that they can better meet the quality requirements of expanded markets. New and diverse food products from rice that are easy to prepare, have flavor and texture appeal, and are economical to manufacture, are needed to increase the total consumption of rice both here and abroad.

USDA PROGRAM

In the Western Utilization Research and Development Division, basic and applied research on rice is conducted at the Division headquarters, the Western Regional Research Laboratory in Albany, California. Basic studies involve chemical, physical, and biochemical investigations of rice proteins and of processing. The protein work is concerned specifically with isolation and characterization of the globulin and glutelin proteins of the endosperm. Effects of processing on quality of cooked rice are being studied. Preparation of high-protein rice fractions by means of fine-grinding and air-classification is under exploratory investigation.

The Federal program of research in this area totals 3.8 professional man-years. Of this number 2.2 are assigned to chemical composition and physical properties; 1.6 to new and improved food products and processing technology.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Rice Proteins. Investigation of processing, cooking, and nutritional qualities of rice, leads repeatedly to questions concerning rice proteins. Rice, as now available, is a food that requires protein supplementation to sustain healthy human life, although what protein is available in rice has a very high biological value. The proteins of rice also appear to affect processing and cooking quality. As a consequence, fundamental research on the protein constituents of rice is being conducted. Rice protein has been extracted and separated by solubility differences into globulin, prolamine, and glutelin fractions, which are now being characterized. Electrophoretic patterns of rice globulin have indicated 11 or more components. Rice globulin has been found to have an unusually high sulfur content, reminiscent of β -globulin of barley. No such protein has been found in other

cereals. Further characterization is underway, including studies of the amino acid content of individual proteins.

B. New and Improved Food Products and Processing Technology

1. Cooking Characteristics of Rice. Evaluation of the cooking and processing characteristics of rice is important in selecting raw material and developing new processes and products. An objective method to determine degree of gelatinization, and from that the quality of cooked rice, was developed using the Amylograph. Further studies on rice will include use of the new procedure to evaluate means of processing rice to improve its utility for various markets.

2. High-protein Rice Products. Rice could be more useful, particularly for export to underdeveloped nations, if its normal protein content could be enriched. Substantial increases in rice protein content have been obtained by using high-level applications of nitrogen fertilizers at the California State Experiment Station. Three varieties of rice grown at the Station, which contained 9 to 10% protein, were used in processing studies to develop food products of even higher protein content. Turbo-milled and air-classified rice flours were obtained with 16 to 17% protein in 8% of the flour. The remaining material yielded another 5% of flour containing 11 to 14% protein. In view of the high biological value of rice protein, a rice flour containing in the neighborhood of 14% protein, would be a very nutritional food product and of great value in the protein deficient areas of the world, if this process could be made economical. Profitable outlets for the separated low protein fractions must be found.

PUBLICATIONS AND PATENT REPORTING RESULTS
OF USDA AND COOPERATIVE RESEARCH

Chemical Composition and Physical Properties

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New and Improved Food Products and Processing Technology

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RICE - PROCESSING AND PRODUCTS
Southern Utilization Research and Development Division, ARS

Problem. The productive capacity of U. S. rice growers has increased faster than domestic and export consumption over the past decade, thus limiting the income potentially available from this major world food grain. Detailed knowledge of chemical composition and physical properties, as related to processing is needed to guide milling, processing and product development of U. S. rices so that they can better meet the quality and new product requirements needed for expanded markets. New and diverse food products from rice that are easy to prepare, have flavor and texture appeal, and are economical to manufacture, are needed to increase the total consumption of rice both domestically and abroad.

USDA PROGRAM

The Department has a continuing long-term program involving at New Orleans, Louisiana, biochemists and analytical chemists engaged in basic and exploratory studies on the chemical and physical changes undergone by rice constituents during aging of rice after harvest, which will account for the improvement in cooking characteristics observed after storage of milled rice for a few months. Present research involves investigations of the biochemical characteristics of rice as affected by and in relation to aging and processing characteristics, with special emphasis on the susceptibility of rice starch to amylolytic action.

Close cooperation is maintained, under formal memoranda of understanding, with the Louisiana, Arkansas and Texas Rice Experiment Stations, who supply rice samples of known variety and cultural history for the experimental studies. The Rice Inspection Service, Grain Division, AMS, New Orleans, Louisiana, cooperates by providing assistance in milling and grading the rice samples used in the research investigations.

The Federal scientific effort at the Southern Division devoted to research in this area totals 3.7 professional man-years. All of the present effort is on chemical composition and physical properties.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Studies of Chemical and Physical Changes in Rice as Affected by Aging and Processing. Recent research on rice has been directed toward basic investigations of the biochemical characteristics of rice as affected by and in relation to age and processing characteristics. Fundamental information of this type is essential for efficient development of practical processes and products so as to increase the utilization of this grain.

Studies of the chemical and physical changes accompanying the aging of 1961-crop Bluebonnet-50 and Nato varieties of rough rice stored at both ambient temperature (77° F.) and 40° F. were completed. In investigations of the native alpha- and beta-amylase activity of the rices and the susceptibility of the starch to introduced alpha- and beta-amylases, the two varieties closely paralleled each other in overall amylolytic susceptibility and native amylase activity. Native alpha-amylase activity of samples aged at either temperature condition remained relatively constant, whereas beta-amylase activity showed a decreasing trend. The rice starch became more susceptible to amylolytic action during the aging process.

After aging, both varieties gave decreased losses in total solids to treating water at 90° C. The viscometric characteristics of the rices progressively increased during the 10-month aging, the lower aging temperature yielding the lower values. Improvement in the organoleptic characteristics for the aged rices of both varieties paralleled the well-defined changes noted in hydration and viscometric properties. There were no significant changes in the gross chemical composition (starch, protein and sugars) of the aged rough rices over the 10-month period, confirming previous results.

Preliminary results on similar experiments conducted with a second year's (1962) crop of Bluebonnet-50 and Nato rices are generally confirming the earlier findings. The same overall pattern of activity of the native amylase enzymes upon aging of the rice samples was observed. After aging of the rice, the starch became more susceptible to the attack of introduced alpha- and beta-amylases. There have been no significant changes in gross chemical composition of the rough rices over the 6-month aging period. However, water uptake and loss of solids to cooking water have progressively decreased at about the same rate for both storage conditions; and organoleptic properties, particularly cohesiveness after cooking, have improved. These changes are paralleled by an increase in viscometric characteristics. These observations of the difference between fresh and aged rice suggest physico-chemical changes in the nature of the rice constituents, perhaps the starch, as evidenced by its progressive change in viscometric characteristics, affinity for water, and amylolytic susceptibility. Still unknown, however, is the causative agent(s) which brings about such changes.

Observations resulting from a study of the aging process and previous investigations of heat-vacuum treatments of rice have led to the development of a method of effecting changes in freshly-harvested rice which bear striking similarities to those found in aged rice. The method consists of heating rough or white milled rice of 12-13 per cent moisture content in a closed container at temperatures between 90°-110° C. for 3 to 8 hours under controlled conditions which prevent loss of moisture from the grains. Characteristics of the treated rice resemble those of rice which has been aged for a period of 10 months or longer. The product has the hydration properties and pasting characteristics of an untreated aged rice and cooks

to a white, dry, fluffy consistency.

Work is in progress on the compilation, review and analysis of domestic and foreign information on rice physical and chemical properties as recommended by the USDA Rice Research and Marketing Advisory Committee, and the Rice Technical Working Group. (S1 4-12).

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Chemical Composition and Physical Properties

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HUMAN NUTRITION AND CONSUMER USE RESEARCH

Consumer and Food Economics Research Division, ARS
Human Nutrition Research Division, ARS

Problem. The assortment and characteristics of foods available to consumers are constantly changing with the adoption of new production, processing, and marketing practices. Constantly changing also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help carry out the Department's responsibility to advise on the quantity and variety of foods that will assure maximum benefit and satisfaction to consumers, continuous research is essential on the nutritional requirements of persons of all age groups, and on the nutrient and other inherent values of foods and how to conserve or enhance these values in household preparation and processing. Periodic examinations of the kinds and amounts of foods consumed by different population groups and individuals also are essential for evaluation of the nutritional adequacy of diets and to give the guidance needed for effective nutrition education. Such information provides assistance needed in market analyses for different commodities and in the development and evaluation of agricultural policies relating to food production, distribution, and use.

PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of principles and improved procedures for household food preparation, care and preservation; (3) surveys of kinds, amounts, and costs of foods consumed by different population groups and the nutritional appraisal of diets and food supplies; and (4) development of guidance materials for nutrition education programs.

The research is carried out by two divisions of the Agricultural Research Service--the Human Nutrition and the Consumer and Food Economics Research Divisions. Most of the work is done in Hyattsville, Maryland, and at Beltsville, Maryland; some is done under cooperative or contract arrangements with State Experiment Stations, universities, medical schools, and industry. The total Federal scientific effort devoted to research in these areas totals 66.3 man-years. It is estimated that approximately 10.2 man-years is concerned with studies related to grain and grain products.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and microorganisms concerned with defining human

requirements for nutrients and foods are not reported on a commodity basis, though some of the work is applicable to this report. This basic nutrition research represents a total Federal effort of 23.4 professional man-years and is described in detail in the report of the Human Nutrition Research Division. Certain aspects of this research related to grain and grain products are considered briefly in this report.

PROGRESS

A. Nutrient Values of Grain and Grain Products

1. Tables of food composition. The 1963 revision of Agricultural Handbook No. 8, "Composition of Foods...Raw, Processed, Prepared," was completed and carried through to the galley proof phase. About 435 items of grain, grain products, and their preparations are included in the revision. In addition to the major grains and flours which were listed in the previous edition, there are new processed or prepared products including cake, pie, cooky, and roll mixes, on both the dry and prepared bases, and some frozen or chilled cakes, cookies, and pies. The list of breakfast cereals has been expanded to some 60 items including the ready-to-eat kinds and hot cereals, the latter both uncooked and cooked. Many baby foods and some soups containing grain products are also included. Rice and its products account for about 25 of the total number of items in the grains group. There is a dearth of up-to-date reliable information on their composition, especially the mineral composition of rices of various types and forms.

Data in the popular publication, "Nutritive Value of Foods," Home and Garden Bulletin No. 72, have been revised to agree on a weight basis with nutritive values in Handbook No. 8. The revised edition will provide nutritive values of household measures of 512 commonly used foods. Another popular publication, "Conserving Nutritive Value of Foods," Home and Garden Bulletin No. 90, is in press.

2. Vitamin analyses. The distribution of three vitamin B₆ components in selected cereal foods was determined by chromatographic separation of pyridoxine, pyridoxal, and pyridoxamine--and yeast assay of the eluted fractions. Grains and cereal products showed differences between total vitamin B₆ in the unchromatographed extract and the total of pyridoxine, pyridoxal, and pyridoxamine of the chromatographed extract. The latter procedure was considered more reliable.

Among the 56 grains and cereal products analyzed for vitamin B₆ were: Whole grains, barley, corn, popcorn, rice, rye, and wheat; cornmeal and five kinds of flour; six breads; seven cereals to-be-cooked; nine ready-to-eat cereals; five precooked infants' cereals; and egg noodles, macaroni, spaghetti, and wheat germ. The grain products generally contained large proportions of vitamin B₆ as pyridoxine or pyridoxal; wheat and rice had over 70 percent of the vitamin as pyridoxine and corn over 50 percent as pyridoxal; barley and corn contained as much as 30 percent as pyridoxamine. Most whole grains and

cereal products made of whole grains contained 2 to 4 micrograms of vitamin B₆ per gram, while other cereal products such as all-purpose flour, white bread, precooked rice, noodles, macaroni, and spaghetti generally contained less than 1 microgram per gram. Part of the loss in processing may be attributed to refining as shown by the relatively large amount of vitamin B₆ in wheat bran (8 micrograms per gram) as compared to all-purpose flour (0.58 micrograms per gram). The studies are being summarized for publication.

The nitrogen content of whole grains and cereal products simultaneously analyzed for vitamin B₆ showed no relationship to the content of vitamin B₆ in these products. Products which had been refined (e.g., removing bran from whole wheat) had much lower vitamin B₆ to nitrogen ratios than did whole grains, indicating much greater losses of the vitamin than of nitrogen. For instance, as an extreme example, the nitrogen content of bran was 1.86 percent, that of all-purpose flour, 1.85 percent, although vitamin B₆ content of the bran was some 15 times greater than that of flour.

Research continued on procedures useful for B-vitamin analyses to permit characterization of B-vitamins in foods and their overall distribution in the food supply. A procedure has been developed for the quantitative determination of pyridoxine (vitamin B₆) as pyridoxal cyanohydrin. Studies will be continued to apply this chemical procedure to the assay of vitamin B₆ in food extracts and to verify results by comparisons with those of the microbiological assay.

An improved method for thiamine determination has been developed. The conditions of the 6-aminothymol colorimetric reaction were changed so that a stable fluorescent compound was produced with thiamine. The fluorescence made possible measurements at much lower concentrations and appeared to be simpler than the usual thiochrome reaction.

3. Proteins and amino acids. A manuscript was published describing a method developed for assay of alanine using Leuconostoc citrovorum 8081 and providing data for 48 proteins and foods, including barley, corn germ, whole germ, whole oats, brown rice, white rice, whole rye, whole wheat, wheat flour, and wheat germ.

Protein-rich mixtures of foods from plant sources are being developed and their nutritive values determined in contract research using Public Law 480 funds at Jerusalem, Israel. Wheat flour, bulgur, soybean flour, chick peas, sesame flour, and sunflowerseed meal were analyzed for content of total nitrogen and of the three amino acids (lysine, methionine, and tryptophan) which limit the nutritive value of most plant proteins. The values obtained were used as a basis for preparing eight mixtures expected to have relatively high biological values. The nutritive value of the eight mixtures, each prepared to contain 25 percent protein, was assessed on rats by determining protein efficiency ratio, digestibility and biological value, and net protein ratio.

B. Properties Related to Quality and Consumer Use of Grain Products

1. Flour measurements. A study was made of the weight-volume relationship of sifted and unsifted flour and its significance in regard to quality of home-prepared baked products. Recent changes and variance in recommendations made by industry regarding methods of measuring flour for household uses made it necessary to obtain information on flour from a number of sources in order to make sound recommendations to consumers. Both all-purpose and cake flour varied less among replicates when the flour was sifted before measuring than when it was measured without sifting. Unsifted flour spooned directly from the flour container varied less in weight per cup than unsifted flour dipped with a cup from the flour container. Unsifted, spooned flour could be adjusted to the approximate weight of a cup of sifted flour by removing two level tablespoons of flour after measuring. No difference was noted in the quality of baked cakes and muffins made with sifted and unsifted flour when the volume of unsifted flour was adjusted in this manner. When unsifted flour was used without adjustment in volume, muffins and cakes were less acceptable than products made with sifted flour.

2. Pastry mixing methods. Two methods of mixing pastry dough which make high quality pastry with less than the usual amount of fat were developed. One of the mixing methods uses liquid cooking oil, the other uses solid fat. In the oil method water and oil together, both at room temperature, are sprinkled into the dry ingredients while blending with an electric mixer at lowest speed, for 3 minutes. The even distribution obtained by sprinkling the oil and water into the dry ingredients results in a tender, flaky pastry. Corn, cottonseed, soybean, and safflower oil work equally well.

Even distribution of fat and water also is responsible for the success of the solid fat method which allows the use of less fat than usual. Room temperature fat is blended into the dry ingredients with an electric mixer at lowest speed for 2 minutes, then water is sprinkled in and blended 1 minute.

How-to-do-it instructions were released to the general public.

3. Qualities of foreign and domestic rices. A report was completed for publication as a technical bulletin on the quality evaluation of foreign and domestic rices, which summarized the research on rice by four Divisions in ARS (HN, SU, WU, and CR). Quality characteristics of both raw and cooked rice from 33 countries and the United States are reported.

Color of raw rice was associated with completeness of milling; differences in lightness and yellowness were also noted. The parboiled rices were generally darker and more yellow than the regular milled samples; samples from India were the darkest.

The starch granules in short-grain rices generally had lower gelatinization temperatures and were altered more by heat than starch granules in medium- and long-grain varieties. All samples tested from Australia, Chile, Egypt,

France, Greece, Italy, Korea, Portugal, Spain, and Turkey, and most of those from Japan had high heat alteration values; those from Colombia, Ecuador, Mexico, West Pakistan, and the Philippines, and all but one from India had low values and those from the other countries were intermediate or varied.

Distinct differences in the appearance of regular milled rices from various countries were noted after cooking. Differences in appearance scores of the rices were greater among individual lots from different countries than among long-, medium-, and short-grained varieties. The long-grain kernels tended to split longitudinally and the short-grain samples to slough. Most of the regular milled rices had fuzzy edges and showed some sloughing. Parboiled milled rices increased in volume, but otherwise changed little in appearance during cooking.

Cooked kernels of parboiled milled rices were well-separated grains; most of the regular milled rice samples were slightly sticky and clumped. The most and least cohesive samples came from India. Cohesiveness or stickiness increased from long- to medium- to short-grain types of rice. Differences in cohesiveness were greater within a grain type from different countries than among grain types within a country.

Most of the cooked rice samples were fairly tender and firm--of optimum doneness. Parboiled milled rice samples were more firm and chewy than the regular milled rice samples.

Pronounced flavors, not typical of domestic rice, were evident in the rices from foreign countries. The flavors found in the cooked rices were attributed to such factors as: Storage conditions; water used in cultivation, milling, or parboiling; and fermentation during the parboiling process. The flavors were described as musty, smoky, medicinal, oily, rancid, and bitter.

C. Nutrient Functions

Proteins. Basic research using small animals and microorganisms is contributing to an understanding of the influence of type of carbohydrate on lipid and protein metabolism and to our knowledge of factors influencing the physiological response to protein-and carbohydrate-containing foods such as the cereals. Protein components in the blood serum of rats, particularly rapidly moving components (PA), varied with diet and with age. PA was present more often and in larger amounts with fasted rats fed a sucrose-containing diet than with rats of comparable age on a starch-containing diet. With either carbohydrate, more PA was generally present in the serum of 350 day-old rats than in that of 150 day-old animals. With glucose, PA was present in small amounts in a larger percentage of rats, and no age effect was apparent. The percentage of 150 day-old sucrose-fed rats with serum containing PA was higher in nonfasted than in fasted rats; the reverse was observed with glucose. Lipid material was found in the PA components.

The presence and amount of these components may provide an additional means of measuring response to diet and may prove a valuable tool for studying lipid transport.

The amino acid concentration of cell pools from Tetrahymena pyriformis was significantly higher when carbohydrate was supplied as glucose than when present as dextrin. This concentration difference appeared to be independent of osmotic effects in young cultures. The concentration of alanine, glycine and glutamic acid were higher, while those of serine and threonine were lower in cells from glucose media.

D. Requirements for Nutrients

1. Preadolescent age group. Cooperation has continued with experiment stations in the Southern Region (S-28 revised) for investigation of metabolic patterns and for assessing requirements for and utilization of selected nutrients by preadolescent children. In 1962 at Blacksburg, Virginia, 12 preadolescent girls were maintained on controlled diets with variation in the amount of protein (entirely from plant sources) and in the amount of riboflavin. Analyses completed for intake and outgo of fat suggest that the amount of fecal fat excreted by the subjects was about twice the amount of fat excreted by subjects on controlled diets in earlier studies, where the protein was mainly from animal sources, although the content of total fat in the diets was comparable.

2. Young adults: Amino acid patterns in food proteins. Combined nitrogen-balance data for 35 adults are being analyzed statistically to determine the influence of several factors upon nitrogen balances on diets containing the FAO pattern of essential amino acids and the patterns in nonfat milk solids, whole egg, oatmeal, peanut butter, and wheat flour. The studies were made under contract at four locations (Alabama, California, Oklahoma, and Wisconsin).

E. Food Consumption and Diet Appraisal

1. Food consumption and dietary levels. A report of the findings of the food consumption survey of beneficiaries of Old Age and Survivors Insurance made in Rochester, New York in the spring of 1957 has been completed. The survey included 283 1- or 2-person households. During the survey week, food brought into the kitchens of these households averaged about the following amounts per person: 4 quarts of whole milk or its equivalent in milk products; 4 pounds of meat, poultry, fish; 1/2 dozen eggs; 10 pounds of vegetables and fruits; 2 pounds of grain products (in terms of flour); 1 pound of sugars and sweets; and 3/4 pound of fats and oils. The total money value of all food per person was \$8.12. Nutrients from this food more than met the National Research Council's recommended allowance for the average person. However, less than half (44 percent) of the households had diets which met in full the recommended amounts for all nine nutrients (good diets). Nearly three-fourths of the households had diets that met two-thirds of the

recommendations for all nutrients (good and fair diets). The nutrients which fell below the recommended allowances most often were thiamine and calcium.

The series of food surveys conducted in low-income areas to aid in the study of the effects of food distribution programs on diets of families has been extended to include a survey carried out in Choctaw County, Oklahoma and in Pensacola, Florida. These were conducted cooperatively with the Marketing Economics Division, Economic Research Service as were similar surveys reported previously.

A food consumption survey was carried out in the District of Columbia that will provide information on the diets of households and of individuals. The study was undertaken primarily as a pilot survey in developing procedures for the next Nationwide survey proposed in the Department's long-range program.

The nutrient content of the per capita food supply is calculated and published each year, using data on estimated quantities of foods consumed (retail-weight basis) as developed by the Economic Research Service. This series, with estimates extending back to 1909, is the only source of data on year-to-year changes in the nutrient content of the U. S. per capita food consumption.

A survey conducted by the Census for the Consumer and Food Economics Research Division has provided information on quantities of enrichment ingredients supplied to processors in fortifying such cereal products as commercial or family flour, ready-to-eat and hot cereals, and cornmeal and hominy grits. The up-to-date findings will be incorporated in a complete revision of the nutritive value of the national food supply now in progress.

2. Food management practices. The results from three small studies based on records kept by the homemaker on the kind, amount, and nutritive value of foods used and discarded in households have been prepared as a journal article. In terms of total calories available for consumption, discarded edible food averaged 7 percent in St. Paul, Minnesota; 8 percent in DeKalb County, Missouri; and 10 percent in Los Angeles, California. A study using "recall questions," instead of records, with a random sample of 300 households in Minneapolis-St. Paul in the winter of 1960 is currently being processed.

A published report on household practices in handling and storing commercially frozen foods, based on surveys in two cities, indicate that household practices alone would not cause serious quality deterioration of frozen foods.

A new study has been initiated (under contract) of the management practices of urban and farm home freezer owners in Fort Wayne, Indiana and a nearby rural area. The survey is designed to obtain information on such actual management practices of home freezer owners as the kinds, amounts, sources, prices, and rate of turnover of foods frozen and stored in the home.

3. Development of food budgets and other basic data for food and nutrition programs. The ongoing program of interpretation and application of nutrition research findings to practical problems for use by nutritionists, teachers, health workers, and other leaders concerned with nutrition education or nutrition policies has involved the preparation or review of articles and publications, talks, television interviews, and participation in various conferences and committees.

With the publication of the report "Family Food Plans and Food Costs" the technical work on the development of the Department's current low-cost, moderate-cost and liberal food plans was completed. The continuing phases of the work on individual and household food budgets consists in the regular pricing of the food plans for publication in Family Economics Review, and in dissemination of information concerning them through such popular publications as "Family Food Budgeting for Good Meals and Good Nutrition," through filmstrips ("Food for the Young Couple"), and through correspondence, talks and committees (such as the Advisory Committee to the Bureau of Labor Statistics on their City Workers' Standard Budget).

Progress on the revision of Handbook No. 16, "Planning Food for Institutions" has focused primarily on the food purchasing guide section. Publications in preparation that are designed for the use of teachers, extension workers and other leaders are (1) a semi-popular publication on nutrition in the series Facts for Nutrition Programs; (2) a report on fat and related components in U. S. diets; and (3) a study of the relative economy of foods.

Nutrition Committee News, a bimonthly periodical prepared for members of State nutrition committees and other workers in nutrition education provides one channel for disseminating pertinent information and for reporting nutrition education activities. Examples of subjects of current interest covered during the report period are: "Nutrition Aspects of Selected Studies of Cardiovascular Diseases--Implications for Nutrition Education," "Planning Nutrition Programs for Elementary School Teachers," and "Food Guides--A Teaching Tool in Nutrition Education."

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III. MARKETING AND ECONOMIC RESEARCH

GRAIN - MARKET QUALITY

Market Quality Research Division, AMS

Problem.

Grain and cereal products are subject to damage or deterioration in quality while in marketing channels through normal metabolic changes, by the action of micro-organisms, and by the attack of more than 50 species of stored-product insects. Safe storage of grain, flour, and cereal products for extended periods is a problem of immediate concern to military and civilian defense agencies. To maintain the quality of these products, more precise information is needed on the changes that occur in handling, storage, and transportation of these materials and of the products manufactured from them. To insure uniform and standardized products in the marketing channels and more equitable prices to all concerned, new and improved methods and techniques for measuring quality factors need to be developed for use in the inspection, grading, and standardization procedures. There is urgent need for more effective methods for preventing insect damage and contamination during storage, handling, processing, packaging, transportation, and retail distribution. The need is critical for effective pesticides and application methods that can be used in the marketing channels without leaving objectionable residues. Even more desirable is the development, wherever possible, of effective preventive and control measures utilizing biological, physical, mechanical or other nonchemical means that would reduce or completely eliminate the application of pesticidal chemicals

USDA PROGRAM

The Department has a continuing program involving chemists, engineers, and plant pathologists in basic and applied research on the quality evaluation, quality maintenance and development of objective methods for quality evaluation of cereal grains. The research is conducted at Beltsville, Maryland, and Watseka, Illinois, and also by research contract with Shuman Laboratories, Battle Ground, Indiana.

The program includes the following foreign projects under PL 480: A grant to the Israel Institute of Technology, Haifa, Israel, provides for a study to develop tests for nutritive value of cereal grains and feeds. Its duration is 4 years, 1960-1964, and involves PL 480 funds with a \$103,785 equivalent in Israeli pounds.

A grant to the Agricultural Higher School, Poznan, Poland, provides for a study of the effect of microflora of wheat flour on its stability, biochemical, and technological properties. Its duration is 4 years, 1961-1965, and involves \$13,091 equivalent in Polish zlotys.

Also, there is a continuing program involving entomologists and chemists engaged in basic and applied research on problems of insect infestation, damage, and contamination of grains and cereal products in the marketing channels.

The work at Manhattan, Kansas, and Tifton, Georgia, is in cooperation with the respective State Agricultural Experiment Stations. The work at Tifton, Manhattan, Savannah, Georgia, and Watseka, Illinois, is in cooperation with the Agricultural Stabilization and Conservation Service, and one professional man-year of effort at Manhattan, Savannah, and Watseka is supported by Commodity Credit Corporation funds. The CCC also makes available various commodities and storage facilities for experimental use. There is cooperation with engineers of the Transportation and Facilities Research Division on matters relating to storage structures and aeration; and with the Field Crops and Animal Products Branch of this Division in studies relating to quality maintenance during storage, and on quality evaluation of grains and cereal products. There is cooperation with growers co-operatives at Manhattan and with various industry groups at all locations. There is also overall cooperation with the State Experiment Stations in Regional Project WM-16, "Maintaining Grain Marketability by Insect Control in Storage."

Much of the work at Savannah, Georgia, has cross-commodity application. Although the work on insecticide evaluation, insecticide residue analysis, and insect-resistant packaging has a direct relation to grain and cereal products, only a part of the manpower has been charged to this area. The entire program is discussed in Area 13.

Contract research included work with the University of Georgia, Athens, Georgia, and the Auburn University Agricultural Experiment Station, Auburn, Alabama.

A contract with the Hebrew University in Rehovot, Israel, provides for extensive studies on the effect of ethylene dibromide-fumigated feed on domestic farm animals. It became effective in 1961, continues to September 1964, and involves PL 480 funds with a \$98,197 equivalent in Israeli pounds.

Another contract with the Hebrew University at Jerusalem, Israel, is for a study of the influence of environmental conditions on the population dynamics of the khapra beetle. It became effective in 1961, continues to October 1964, and involves PL 480 funds with a \$44,296 equivalent in Israeli pounds.

A contract with the Administration of Agricultural Reserves and Surpluses, Montivideo, Uruguay, is for the study of underground storage of corn in airtight silos in relation to maintaining quality and preventing insect infestation during long-term storage. It became effective in 1962, continues to May 1967, and involves PL 480 funds with a \$59,906 equivalent in Uruguayan pesos.

A contract with the Instituto Superiore di Sanita in Rome, Italy, is to study the fate of insecticide residues on wheat during storage, milling, and baking or processing into wheat products. It became effective in 1963, continues to March 1967, and involves PL 480 funds with a \$98,319.16 equivalent in Italian liras.

A contract with the Direzione Generale dell' Alimentazione, Ministry of Agriculture and Forests, Rome, Italy, is for the study of insect infestation in macaroni, noodles, and spaghetti, and of ways to prevent this infestation. It became effective in 1962, continues to November 1965, and involves PL 480 funds with a \$42,621.90 equivalent in Italian liras.

The Federal scientific effort devoted to research in this area totals 24 professional man-years divided as follows: Quality maintenance and evaluation 6.0; basic biology and ecology 3.6, insecticide evaluation 1.8, and nonchemical control 0.6 at Manhattan, Kansas; insecticide evaluation 0.8, and nonchemical control 0.2 at Tifton, Georgia; insecticidal control 0.3 and nonchemical control 0.7 at Watseka, Illinois; insecticide evaluation 2.1, insecticide residue analysis 2.0, and insect-resistant packaging 2.5 at Savannah, Georgia; program leadership 2.4 at Hyattsville, Maryland; and contract research 1.0.

Line project MQ 1-8(C), a study of the effects of ethylene dibromide fumigant mixture on egg laying, was discontinued with the completion of the contract research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement and evaluation of quality

1. Quality Indicators for Stored Wheat. Samples of the hard red winter wheat varieties, Triumph, Bison, and Red Chief, and the hard red spring wheat varieties, Spinkcota, Selkirk, and Conley, of the 1962 crop were stored for 44 weeks at 75° F. Sedimentation values decreased during the storage period with the greatest decline exhibited by the two hard red spring varieties, Selkirk and Conley. The fat acidity values increased faster near the end of storage period than initially. The generally recognized poor quality wheat varieties, Red Chief, and Spinkcota, showed in general less changes in

quality due to storage than the strong, good quality wheats. Samples of the highest moisture level of 16 percent evidenced generally greatest decline in overall quality, with the 14 percent moisture samples less, and the 12 percent moisture samples the least. Grain stored at 86° F. declined more in chemical, baking, and other quality properties than wheat stored at 75° F. (MQ 3-3)

2. Effect of Excessive Heat on Corn Quality During Artificial Drying. (a) Reducing sugar content and diastatic activity. Among the chemical and physical properties of the corn grain examined as possible indices of damage by high temperatures during artificial drying, diastase activity was the property having the greatest differential between unheated samples and samples dried at 200° F. Diastase activity demonstrated an inverse linear correlation with increasing drying temperatures significant at the 1 percent level. Diastase activity was more sensitive to inactivation by heat than esterase activity or dehydrogenase activity as measured by tetrazolium salts, but it did not have sufficient accuracy or repeatability for predicting heat damage in corn. Diastase activity was not greatly affected by grain moisture in the range of 7 to 21 percent.

(b) Corn tenderness as an indication of damage by heat. Although this technique has been used successfully in assaying tenderness of various commodities, little or no correlation was found between corn tenderness and damage by heat.

(c) Viscosity measurements of mixtures of ground corn and dilute alkali solutions as an indication of damage by heat. Preliminary tests with this technique indicated that mixtures of ground heat-damaged corn and dilute alkali solutions gave higher viscosity readings than mixtures containing ground unheated corn and dilute alkali solutions.

(d) Moisture distribution in corn samples as an indication of damage by heat. This technique involves making a high frequency electrical capacitance measurement which is directly related to the total moisture content of the corn sample and subsequently making a direct current resistance measurement of the same sample. The resistance values are inversely related to the logarithm of the surface moisture of the corn sample. When the capacitance and resistance values for normal, undamaged corn are plotted on a semilog chart a straight-line curve is formed. The values for damaged corn, when plotted, are offset from this straight-line curve in an amount which appears to be related to the amount of damage to the corn. A significant correlation ($r=0.85$) was obtained between the magnitude of the offset in units of capacitance and the starch yield percent. The series of samples used were artificially dried by the Transportation and Facilities Research Division facility at Purdue University and the starch yield determinations were made by the Shuman Chemical Laboratories of Battle Ground, Indiana.

This offset value may also have some relationship to the viability of the corn but further investigative work is needed before any conclusion can be drawn.

(e) Glutamic acid decarboxylase activity as an indication of damage by heat in corn. This technique is being evaluated and improved. It appears to have some merit as a laboratory method and should serve as a check on other methods. (MQ 3-18)

3. Moisture Measurement and Equilibria in Grain. (a) Spectrophotometric measurement. A modified near-infrared spectrophotometric method of moisture determination of wheat has been developed. The methanol extraction of the earlier method is eliminated saving considerable time. It makes use of the fact that water absorbs light at 1.93 microns wavelength. The extent of the absorption depends upon the amount of water present in the sample of ground wheat through which the light passes. Results obtained for ground wheat show that sensitivity of 0.1 percent is readily obtained.

(b) Study of hysteresis. A new approach to the study of hysteresis effects in wheat has been undertaken. Kernels of wheat of known moisture content which have been colored with an organic dye are mixed thoroughly with other kernels which are not dyed and have a different known moisture content. The mixture is held in a sealed container at constant temperature until equilibrium conditions are attained. This requires approximately 40 days at 76° F. The hysteresis effect is determined by separating the dyed from the undyed kernels by hand and making a moisture determination on each. When the original difference in moisture content between the dyed and undyed kernels is approximately 5 percent the difference between them at equilibrium at 76° F. is 0.7 percent. This difference at equilibrium gradually decreases as the original difference in moisture content falls below 5 percent. Studies are also being made on the effect on this equilibrium of temperature, pressure, kernel size, relative weights of high and low moisture kernels and successive wettings and dryings. (MQ 3-23)

4. Sampling Research. Cooperative agreements were prepared and signed to cover research on the mechanical sampling of grain. Grain industry cooperators include Cargill, Inc., South Dakota Wheat Growers Association, R. F. Gunkelman & Sons, Farmers Union Grain Terminal Association, and F. H. Peavey and Company. Mechanical sampler manufacturers include the Dean Gamet Company, The Gustafson Manufacturing Company, The Erling K. Strand Company, Wilson Machinery Company, and Canadian Anglo Machinery and Equipment Company. Grain sampling research was conducted at Wolf Point, Montana; Aberdeen, South Dakota; Grandin, North Dakota; Minot, North Dakota; Crookston, Minnesota; and Minneapolis, Minnesota. Various lots of wheat and barley were carefully cleaned to our specification. Typical screenings were added to

these lots to provide grain with known FM and dockage content. The grain was sampled mechanically as it was loaded into boxcars. It was resampled by standard grain probes and by additional mechanical probes as it moved to destination and during unloading following a plan developed to yield maximum statistical data.

Research was directed toward designing and building a pneumatic sampler to meet the needs of the Watseka Bin Storage Project. Air-flow requirements were measured and an experimental double-wall sampling tube built. A second pneumatic sampler of improved design has been built and is ready for testing. (MQ 3-24)

5. Standardized Lighting Conditions for Grading Grain. The color background work mentioned in the 1962 report has been completed and preparation of a manuscript is in progress. After screening numerous materials and background colors, four selections were made for more concerted study with the Macbeth TC 440 examolite as a light source.

A total of 2,520 examinations were made. Analysis of the data by the "Duncan test" method, using the data of all nine men, failed to show significant differences between colors on some commodities. When data were stratified into two groups, based on experience of the nine men, and reanalyzed, 66.6 percent of the data showed a definite difference in results obtained on buff and blue X backgrounds. (MQ 3-30)

6. Test Weight-Flour Yield. The four general classes of wheat have been studied to find what physical and chemical characteristics are related to flour yield. So far, the following factors have been studied: Test weight per bushel, 1,000-kernel weight, density, average kernel volume, kernel size, pentosan content, pearling index, and bran content. Statistical analyses of the test results are not yet complete, but for the hard red winter wheats all these factors show significant correlations with flour yield. There are indications that all the classes do not exhibit the same milling behavior and therefore the correlations of these factors with flour yield cannot be expected to be the same for all classes. The results of these analyses will be used to develop better methods for predicting flour yield. (MQ 3-36)

B. Quality maintenance in storage

1. Oxidative Deterioration of Dried Corn. The results of these studies indicate that corn seed with a moisture content of 8 percent or less, can be stored at 68° F. and below at levels of oxygen ranging from 0 to 100 percent, without a severe reduction in germination or growth of seedlings. Methods of chemical analysis were adapted to study injuries on very dry corn in storage caused by oxygen.

In general, peroxide formation was not directly related to the storage life and vigor of the seed. Assays for carotenoids showed a decline of pigments during storage which apparently was correlated with the amount of oxygen in the storage atmosphere. This loss of pigment appeared to be one of oxidation and was not correlated with seed moisture. No significant variation was revealed between the total fat content of seeds of different moisture contents stored at different oxygen levels. Results of phosphorous analysis were disappointing due to lack of suitable methods for analyzing the small fractions involved. Studies of conductivity of seed leachates indicated that results of these tests might be more reliable in the general assessment of stored grain rather than as tests for germination.

Respiration studies of very dry corn revealed extremely low rates of carbon dioxide production. These results and other corroborative evidence could suggest that the carbon dioxide obtained was not the result of enzymatic respiration. (MQ 2-34)

2. Corn Storage Research. Studies of the effect of various chemicals as inhibitors of fungus development showed little promise and were discontinued. Sampling and pathology tests on corn stored at the CCC binsite have been continued and are revealing the organisms infecting the corn. Studies of the airborne fungi in the atmosphere of the binsite, both in the bin and surrounding atmosphere, have been initiated. In addition, the survey of the total fungus population of the stored corn is being continued. (MQ 0-0-2 (CCC))

3. Microflora of Wheat. In PL 480 research being conducted in Poland, seventy-eight samples of Polish wheat and eight samples of wheat imported from the United States and the Soviet Union were evaluated qualitatively and quantitatively with regard to their external and internal microflora. This microflora was found to consist of 62 species of bacteria and 58 species of fungi. These results are in line with those reported by numerous other investigators and did not reveal the presence of any previously unreported species. No significant differences in microflora were found among the 78 soft wheat samples of the 1961 crop from 17 areas of Poland. Ten samples of the 1962 crop from the Poznan region were found to be virtually free of internal fungi and bacteria. Eight hard wheat samples from the United States and the Soviet Union were found to be completely free of internal fungi and bacteria. No significant differences were found between the degree of external contamination of the imported wheat and that of the Polish wheat.

It was found that one species of an aerobic, spore-forming bacillus consisted of several biochemical strains and it is believed that this finding may be of "great practical significance, as far as the qualitative evaluation of flour is concerned." A number of fungi and spore-forming bacteria exhibited marked antagonism toward Bacterium herbicola.

If it can be assumed that B. herbicola is one of the dominant bacteria on healthy seeds, then its presence might serve as an indicator of the health condition of grain. (E21-AMS-7(k))

4. Underground Storage of Corn. This research project concerned with the underground storage of corn in airtight silos is being done in Uruguay under a PL 480 grant. After preliminary studies, experiments were started on the construction of underground silos. Two experimental silos have been constructed each to hold 550 tons. Both are now ready for corn and the actual research study is being initiated. (S9-AMS-6(a))

C. Prevention of insect infestation

1. Basic Biology and Ecology. In a study to find whether the air movement in mechanically aerated bins of grain has adverse effects on stored-grain insects, it was found that the interstitial air in all nonaerated bins contained a percentage of carbon dioxide considerably in excess of that in normal air or in aerated bins. This condition existed in wheat, corn, and grain sorghum in 3,250-bushel circular metal bins where observations were made over a period of 3 months. There was a pronounced reduction in carbon dioxide concentration of interstitial air in bins aerated with outside air after 2 weeks of fan operation at the normal airflow rate of 0.1 cubic foot per minute. No correlation was evident during the period of observation between changes in grain temperature or moisture within a bin and the composition of the interstitial air in the same bin. (MQ 1-18)

A series of laboratory tests was conducted to determine the effect on the development of rice weevils in aerated wheat by varying temperature, relative humidity, or rate of air movement, one factor at a time. Twenty 3-inch diameter downspout tubes filled with wheat were used in each test, and they were placed in a small insulated room where the temperature and relative humidity were maintained at a constant preselected level. At 80° F. and 60% relative humidity, conditions favorable to the insects, the nonaerated tubes produced fewer progeny than did the aerated tubes. The air circulation tended to increase the moisture content of the grain, making environmental conditions more favorable for reproduction. With the high moisture content in grain caused by circulating air at 90% relative humidity and a high flow rate of 1 cubic foot per minute per bushel, the grain became moldy, crusted, and production of rice weevil progeny was limited. When circulated air contained only 30% relative humidity the lower flow rates dried the grain the least and produced the highest number of progeny. With air at 60% relative humidity but lower temperatures of 70° and 60° F., the rate of development and total number of progeny per tube were reduced in both aerated and nonaerated wheat. (MQ 1-18)

An evaluation was made of the effect of moist or dry nitrogen, carbon dioxide, or normal air at 86° F. and at 3 flow rates toward pre-conditioning 2-week old confused flour beetle adults for susceptibility to fumigants. The treatments in decreasing order of effectiveness were dry nitrogen, moist nitrogen, dry CO₂, moist CO₂, moist air, and dry air. There was no linear correlation between gas flow rate and later fumigant susceptibility. (MQ 1-31)

Twelve hours of exposure to moist or dry carbon dioxide or nitrogen at a flow rate of 100 cc. per minute resulted in the following weight losses of confused flour beetle adults: 20.29% for dry nitrogen, 14.99% for dry carbon dioxide, 8.09% for moist nitrogen, and 3.79% for moist carbon dioxide. Controls with either dry or moist room air lost an average of 3.85% in weight. (MQ 1-31)

A new standard concentration-mortality curve for adult confused flour beetles treated with the fumigant mixture of 80% carbon tetrachloride and 20% carbon disulfide for 24 hours at 80° F. showed that the present laboratory stock culture is somewhat more susceptible than was reported about 40 generations ago. (MQ 1-31)

Information reported under Line Project MQ 1-18 suggests that the typical atmosphere in the natural environment of stored-grain insects may contain a greater amount of carbon dioxide than in normal air. It has also been found that a high level of carbon dioxide exists in culture jars in the laboratory where stored-grain insects are reared. The question arises as to what is a "normal" atmosphere for stored-grain insects. A series of tests is under way with various ratios of oxygen and carbon dioxide to find which will maintain, elevate, or depress respiration and at what point the atmospheric environment becomes detrimental to these insects. Preliminary data indicate that for every 50 percent decrease in oxygen concentration the respiratory quotient is lowered by 23 percent. It is also calculated that in some cases the basal metabolic rate of 2-week old confused flour beetle adults is about 10 times that of an adult human. (MQ 1-31)

A significant condition during nitrogen or carbon dioxide preconditioning of insects is the temporary unavailability of oxygen. Following sublethal preconditioning there is a brief period of elevated respiration for recovery and to repay the oxygen debt incurred. Theoretically this period of high respiration would be when the insects are most susceptible to the action of fumigant gases, so studies were made to learn the extent and duration of elevated respiration. After confused flour beetle adults were held in nitrogen for 2 hours they reached a maximum recovery respiration of 28 percent above normal within 30 minutes after the preconditioning period, and this lasted for 70 minutes. There was a gradual decline in respiration rate during the remaining 4 hours of observation. Insects held

in carbon dioxide for 2 hours reached a maximum respiration of 58% above normal at about 60 minutes after preconditioning, and this lasted for nearly 2 hours. (MQ 1-31)

During the nitrogen preconditioning it was found the gas stream had an oxygen contamination of less than $\frac{1}{2}$ of 1% by volume. Even though the insects were immobile and in anesthesia, it was found they were able to use oxygen even from this minute source, but the average of constant oxygen uptake was about 45% below the normal rate of use. During this time no carbon dioxide production could be detected. (MQ 1-31)

An ecological study is under way to determine the interrelationships and effects of different grain moisture contents and different levels of different kinds of dockage or foreign material in the grain upon the attractiveness of the grain to different kinds of insects and upon the fecundity of various insects when living on the grain. Four series of tests with confused flour beetles and one with red flour beetles have been conducted thus far. One strong trend that is readily apparent is a tremendous increase in number of progeny produced by these insects as the amount of foreign material in the grain is increased. (MQ 0-0-1(CCC))

Research under a contract with the Hebrew University in Jerusalem, Israel, to determine the effects of various environmental factors on the biotic potential of the khapra beetle is progressing in a highly satisfactory manner. Experiments showed that the larvae developed normally at a population density of 100-140 per 3.5 grams of ground wheat. Higher densities resulted in a slower rate of development. Delay in pupation was noted when larvae were reared on food that had been conditioned by having larvae previously live on it to various stages of development. Feeding studies with khapra beetle excrement that had accumulated in food medium indicated a deleterious effect on the rate of development. Further study will attempt to isolate the responsible factor or factors. Feeding khapra beetle larvae on dried larvae of the same species produced pupae that were heavier and adult females that laid more eggs than in the normal control insects. There was no difference in the percentage of eggs that hatched in the two groups. The above effects of this cannibalistic diet extended to the second and third generation beyond the one to which it was fed. (A10-AMS-11(k))

Seven species of fungi and two of bacteria were obtained from samples of beetles in the Tel Aviv, Israel, area. These organisms are apparently carried in the digestive tract of the insects. When the larvae were placed in a clean culture medium they inoculated the medium and as the organisms developed there was a definite increase in temperature of the medium. Use of a fungicide prevented growth of the organisms as well as the consequent rise in temperature. When

sterilized khapra beetle eggs were placed in clean culture medium they developed normally but there was no temperature increase in the medium and the resulting adults appeared not to be as productive as those reared in the presence of the organisms. (A10-AMS-11(k))

2. Insecticide Evaluation. Eighteen numbered candidate compounds were received at Manhattan, Kansas, from the Savannah, Georgia, station and were tested for repellency when applied on grain. None was outstanding in performance. (MQ 1-15)

At Savannah a method was investigated for applying insecticides to be evaluated in laboratory tests as potential protectants to wheat, shelled corn, rough rice, and farmers stock peanuts. Uniform malathion deposits were obtained by applying a liquid formulation of the insecticide to the interior wall of a 1-gallon glass jar containing the commodity, then mixing the insecticide and the commodity through the tumbling action of rotating the jars mechanically. About 83% of the intended deposit was recovered by chemical analysis. The results from this simple method are in sharp contrast to the 30% recovery from application in a twin shell liquid-solid V-type blender that had been procured because it was reported to be specially designed for effective and uniform applications of this nature. (MQ 1-15)

Preliminary tests were conducted at Savannah to determine the comparative effectiveness against rice weevils of malathion, DDVP, Guthion, Substanz 215, and Velsicol W-24 as protectants on wheat. Initial mortality data indicated that malathion and DDVP were the most effective against both the immature and adult insects. Guthion, Substanz 215, and Velsicol W-24 were relatively ineffective. The duration of effectiveness was not tested in this experiment, but some residue data on DDVP indicated that the rate of loss or degradation of the deposit was rapid. (MQ 1-15)

At Tifton, Georgia, 3 candidate grain protectants were tested in the laboratory for immediate toxicity against confused and red flour beetles and rice weevils, when applied on shelled corn. DDVP, Diazinon, and Bayer 29493 were applied at the rates of 5, 10, and 20 p.p.m. and were compared with the standard malathion treatment. All three were equal to or better than malathion. Diazinon was the only one of the three that prevented reproduction of confused flour beetles at all three rates of application. The phase of the test to determine the duration of effectiveness of the deposits is still in progress. (MQ 1-15)

A proportionate share of the cross-commodity insecticide evaluation work at Savannah, Georgia, has been charged to this area. Although

most of the work is directly applicable, it is not feasible to report only certain portions here or to include all the information under each commodity area. Therefore the entire report is included in Area 13.

3. Insecticidal Control. A wettable-powder formulation of malathion seems to be more effective than the emulsion treatment on the basis of bioassay tests and the occurrence of natural populations in treated shelled corn at Watseka, Illinois. Chemical analyses of the deposits on the corn failed to show any differences between the two formulations. In bioassay tests, malathion-treated corn from aerated bins produced lower overall mortality to test insects than did the treated corn from nonaerated bins. Surface samples of corn produced low mortality whether from aerated or nonaerated bins. Mortalities were higher from the nonaerated bins when corn samples were taken at the 4- to 5-foot or the 11- to 12-foot levels. When supplemental surface sprays of malathion were applied to treated, nonaerated bins of corn there was a lower natural insect population and increased mortality in bioassay tests with samples of corn taken from the surface.
(MQ 0-0-1(CCC))

Twelve fumigations have been conducted in the series to study the behavior of liquid fumigants in 3,250-bushel bins with and without aeration systems. Although certain trends seem to be showing up, no definite conclusions can be reached until the entire series of 20 fumigations is completed.
(MQ 0-0-1(CCC))

Under a research contract with the Auburn University Agricultural Experiment Station a study is being made to determine the nature and extent of insect damage to corn in the Southern states at time of harvest and during storage, and to assess the effectiveness of insect control measures as now used for preventing such damage. The study is being made on the 1962 crop in Georgia, Alabama, and Mississippi. Ten species of stored-product insects were found infesting corn at the time of harvest. The predominant ones were the rice weevil, square-necked grain beetle, and Angoumois grain moth. These three were also the most predominant after 6 months of storage. Sixteen insects per pint of shelled corn were found in Georgia and Alabama and 25.2 in Mississippi at the beginning of storage in October. The average moisture content of the corn at that time was 13.2 percent. At the time of harvest the average insect damage in the 3 states was 12.2 percent. In storage the damage had risen to 14.0 percent in January and 19.2 percent in April. About 88 percent of the corn in Alabama is stored on the ear and 12 percent is shelled. Twelve percent of the ear corn and 25 percent of the shelled corn is fumigated in storage. Protectants are used on 8 percent of the ear corn and 13 percent of the shelled corn.
(MQ 1-30(C))

4. Nonchemical Control. Laboratory tests have been initiated in the preliminary phase of a thorough study of inert dusts as potential protective treatments for grain. Major phases of the research include a study of the effectiveness against stored-grain insects of different types of inert dusts with specific physical properties; the influence of grain temperature and moisture content, as well as type of grain, on the immediate and long-term effectiveness of inert dusts against stored-grain insects; and the relative susceptibility of the major kinds of stored-grain insects to inert dusts. Preliminary results confirm that certain inert dusts produce a high initial mortality of some kinds of insects at the time of treatment, and also a high degree of immediate control over the production of progeny. (MQ 1-15)

One approach to the dual objective of preventing insect damage to corn and of reducing the use of pesticides lies in the development of insect-resistant varieties as hybrids. A series of 43 hybrid corns harvested from variety trials at the Coastal Plain Experiment Station, Tifton, Georgia, was rated for resistance to rice weevil attack during storage, on the basis of the number of progeny able to develop during a 90-day test period. The fewest number of progeny produced was 138 in Greenwood 18, and the largest was 1,426 in PAG 750, the most susceptible of the 43 varieties. Preliminary evaluations of resistance to rice-weevil attack were also made on 646 test lines being worked with by the Cereal Crops Research Branch, ARS. A high percentage of samples showed more resistance than did the hybrids now being grown. Rice weevils were apparently unable to feed or develop at all on some of the selections in which there were no progeny at the end of 90 days. (MQ 1-15)

A PL 480 project has recently been initiated by the Direzione Generale dell' Alimentazione of the Ministry of Agriculture and Forests, Rome, Italy, to study insect infestation of spaghetti, macaroni, noodles, and other pastas, and to find ways of preventing such infestation. It is too early to report any experimental results, but a complete survey of the literature has been made. Also about 375 pasta factories were visited to make preliminary observations and find cooperators for work to be done later. (E15-AMS-9(a))

Observations are being made in 4 quonsets of shelled corn where the aeration system pulls air down through the corn and in 4 where the air is pushed up through the corn, to determine whether the two air-flow patterns may vary in their effect on insect populations in the bins. At Watseka, Illinois, there were fewer insects where the air was pushed through the corn. This confirms preliminary observations made at Watseka last year. But in 4 bins at Ellis and 2 at Crescent City, Illinois, there was no apparent difference in the insect populations in the corn aerated by the 2 methods. Observations are continuing to obtain more conclusive information about the effects of these 2 systems on insect populations. (MQ 0-0-1(CCC))

The vertical aeration ducts used in 3,250-bushel bins at ASCS bin-sites have been helpful in holding down insect populations in stored shelled corn. During cooler months, however, insects have been found to congregate near the floor of the bins, below the level of the duct, sometimes in fairly large numbers. Apparently the influence of the aeration duct may not extend to the floor level of the bin, leaving the grain warmer and with a higher moisture content, both conditions favorable for insect development. Comparative observations in bins with horizontal aeration ducts have shown that the corn was cooled more evenly and fewer insects were present. (MQ 0-0-1(CCC))

5. Toxicology. The concluding series of tests in a research contract with the University of Georgia was to determine whether there was any difference in the effects of ethylene dibromide (EDB) on poultry when the compound was administered as the fumigant residue on oats fed to the hens or when it was introduced directly into the birds' crops as was done during the main body of the research study previously reported. No significant differences were found between these methods of administration. For experimental purposes the direct introduction of the compound is to be preferred because of the easier and more precise control over dosage rates. By either method, it was found that 0.5 mg. of EDB per bird per day, equivalent to 5 p.p.m. in the total diet, fed for a period of 12 weeks caused a reduction in egg weight. The reduction was greater as the dosage rate of EDB was increased. The rate of egg production was not affected by 40 p.p.m. of EDB in the diet, but 80 p.p.m. caused a significant drop and 160 p.p.m. stopped production completely within 7 weeks. At 80 p.p.m. the EDB had no apparent effect on feed consumption, body weight, or mortality of the hens. (MQ 1-8(C))

A PL 480 research project at Hebrew University in Rehovot, Israel, is investigating the effect of ethylene dibromide (EDB) fumigated feeds on farm animals. Of the animals tested thus far, laying hens are the most susceptible to the toxic action of EDB. Rats and cockerels were not apparently affected by 200 p.p.m. of EDB in the diet, as far as growth, feed consumption, sexual development, and general health were concerned. Feeding 2 to 3 mg. of EDB per kg. of body weight daily to milk cows, mature cows, calves, and pigs caused no observable effects. Calves a few days old were seriously affected by feeding of 10 mg. of EDB per kg. of body weight daily and died after a few weeks. At 40 mg. per kg. daily the treatment was lethal after only 2 days. The main symptom was pneumonia. EDB added to artificial rumen was recovered unchanged after 25 hours, indicating that it is probably not decomposed in rumen of cattle. The bromine content of blood was elevated by feeding EDB. High bromine levels were found in the organs of poisoned animals. Acute poisoning of rats by EDB caused biochemical changes similar to those induced by carbon tetrachloride. Supplemental studies are being made on the sorbition and retention of

EDB by various feed products, and on the attempt to develop a simple, rapid method of detection for EDB residues in grain or feed.
(A10-AMS-4(a))

6. Insecticide Residue Analysis. As with insecticide evaluation, the insecticide residue analysis work at Savannah, Georgia, of a cross-commodity nature is reported in Area 13.

A PL 480 research project by the Istituto Superiore di Sanita in Rome, Italy, became effective in 1963 to study in further detail the fate of the residues of several materials when applied as wheat protectants, but it is too early for any results to be reported.
(E15-AMS-8(a))

7. Insect-Resistant Packaging. A part of the cross-commodity packaging work at Savannah, Georgia, has been charged to this area. Although much of the work is directly applicable to grain and to cereal products, it is not feasible to report only certain portions here or to include all the information under each commodity area. The entire report is included in Area 13.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Quality Measurement and Evaluation.

- Baker, Doris. 1962. Fatty Acid Composition of Oil from Damaged Corn and Wheat. Cereal Chemistry, Amer. Assoc. of Cereal Chemists, Vol. 39, No. 5, September 1962. (MQ 3-18)
- Hart, J., and Golumbic, C. 1962. Comparison of Basic Methods of Moisture Determination in Seed. Proceedings of the International Seed Testing Association, Vol. 27, pp. 907-991. (MQ 3-23)
- Kingsolver, C. H., Yeatman, J. N., Boller, R. A., and Thompson, J. A. 1963. Backgrounds and Artificial Lighting for Standardized Grain Inspection. Marketing Research Report No. 606. (MQ 3-30)
- Schroeder, H. W., and Christensen, J. J. 1963. Factors Affecting Resistance of Wheat to Scab Caused by Gibberella zeae. Phytopathology, Vol. 53, No. 7, pp. 831-838. (MQ 3-3)

Prevention of Insect Infestation.

- Fuller, H. L., and Morris, G. K. 1963. The Comparative Toxicity of Ethylene Dibromide When Fed as Fumigated Grain and When Administered in Single Daily Doses. Poultry Science 42(2): 508-514. (MQ 1-8(C))
- Morris, George K., and Fuller, Henry L. 1963. Effect of Ethylene Dibromide in the Diet on the Growth of Chicks. Poultry Science 42(1): 15-20. (MQ 1-8(C))
- Stored-Product Insects Branch. 1962. Insects in Farm-Stored Wheat--How to Control Them. USDA, Leaflet No. 345, 8 pp., Revised October 1962. (MQ 1)
- Stored-Product Insects Branch. 1962. Method and Equipment for Bulk Treatment of Grain Against Insects. USDA, Marketing Bull. No. 20, 7 pp. (BS 1-34)
- Stored-Product Insects Branch. 1963. Sampling Methods for Determining Insect Populations in Stored Grain. USDA, AMS-497, 2 pp. (MQ 1)

RICE - MARKET QUALITY
Market Quality Research Division, AMS

Problem.

Harvested rice is subject to damage or deterioration in quality while in marketing channels through normal metabolic changes, by the action of disease organisms, and by insect infestation during storage either as rough or milled rice. Safe storage of rice for extended periods is a problem of immediate concern to military and civilian defense agencies. To maintain the quality of this product, more precise information is needed on the changes that occur in handling, storage, and transportation. To insure uniform and standardized products in the marketing channels and more equitable prices to all concerned, new and improved methods and techniques for measuring quality factors need to be developed for use in the inspection, grading, and standardization procedures. There is urgent need for more effective methods for preventing insect damage and contamination during storage, handling, processing, and transportation. The need is critical for the development of effective pesticides and application methods that can be used in the marketing channels without leaving objectionable residues. Even more desirable is the development, wherever possible, of effective preventive and control measures utilizing biological, physical, or mechanical means that would completely eliminate the need for pesticidal chemicals.

USDA PROGRAM

The Department has a continuing program involving engineers, chemists, and plant pathologists in basic and applied research on the quality evaluation and quality maintenance of rice. This work is located at College Station, Texas, in cooperation with the Texas Agricultural Experiment Station.

A grant with the Department of Plant Chemistry, Valencia, Spain, provides for a study on objective methods for measuring market quality of rice. Its duration is for 4 years, 1960-1964, and involves P. L. 480 funds with a \$19,390 equivalent in Spanish pesetas.

The Federal scientific effort in this area totals 2 professional man-years: quality evaluation 1.0, quality maintenance in handling and packaging 0.5 and quality maintenance in storage 0.5.

Line Project MQ 2-7, "Cause and development of control of micro-biological, chemical, and physical deterioration of rough rice in relation to off-farm conditioning, handling, and storage in the South Central states," was recently revised.

The Department also has a continuing long term program involving entomologists engaged in applied research on the control of insects attacking stored rice. For several years the research has been conducted at Houston, Texas, in cooperation with various industry groups, the Agricultural Stabilization and Conservation Service, the Field Crops and Animal Products Branch, MQRD, AMS, and the Texas Agricultural Experiment Station. Toward the end of the reporting period the work was relocated at Fresno, California, as part of a Branch action to consolidate several small field stations. This will permit more effective utilization of manpower and equipment.

A continuing program of basic and developmental studies at Savannah, Georgia, involves entomologists and chemists whose research has cross-commodity application. Although much of the work on insecticide evaluation, insecticide residue analysis, and insect-resistant packaging has a direct relation to stored rice, only a proportionate share of that effort has been charged to this area.

The Federal scientific effort devoted to entomological research in this area totals 3.5 professional man-years divided as follows: insecticidal control 0.2 and nonchemical control 1.8 at Houston; insecticide evaluation 0.4, insecticide residue analysis 0.4, and insect-resistant packaging 0.3 at Savannah; and program leadership 0.4 at Hyattsville, Maryland.

Line Project MQ 1-3, "Development of improved procedures for fumigating milled rice in storage," was discontinued.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement and evaluation of quality

1. Long-Grain Milled Rice. An improved apparatus for the alkali test which was developed for differentiating long-grain varieties of milled rice was tested on new varieties. A physical method for differentiating certain newly developed long-grain varieties of milled rice was developed. A rapid light reflectance method for determining degree of parboiling in rice is now being tested.
(MQ 3-12)

2. Objective Measurements for Determining the Degree of Milling of Rice. Additional tests of the rice photometer to determine more suitable wavelengths for measuring the degree of milling of parboiled rice were made. The highest correlation between rice photometer readings and official rice graders' ratings were obtained with the ratio $T_{859} \text{ m}\mu / T_{660} \text{ m}\mu$.
(MQ 3-16)

3. Chemical Indicators of Quality. This P. L. 480 project in Spain confirmed the relationship between amylopectin and quality reported previously and supports the view that molecular weight of amylopectin has an influence on the behavior of rice being cooked. A high amylopectin molecular weight provides the starch granule with an elasticity of structure and resistance to breakage during swelling. Among aged samples, in general, long-grain rices require longer cooking times than short-grain rices; this tendency was also observed when studying the fresh rice samples.
(E25-AMS-1(a))

Total protein does not constitute an index of quality of rice although it has some relationship to quality the heterogeneity of rice grain endosperm was confirmed, particularly that the outer layers are richer in protein than the inner ones. A new rice quality test was based on this fact.

B. Quality maintenance in handling and packaging

The effects of infrared drying of rice and treatment of rice with preservatives have been verified by additional experimentation. Rough rice (air-dried and infrared-dried) with an initial moisture content of 12.4 percent was stored in an atmosphere with a

relative humidity of 85 percent at 30° C. for 33 days and sampled at intervals of 3-7 days. Air was circulated continuously in the storage chamber (continuous aeration). Infrared-dried rice remained at a lower moisture content throughout the experiment. Storage mold infestation of infrared-dried rice treated with preservative was reduced after 3 weeks storage in 100 percent relative humidity at 30° C. in comparison to similar samples that were not treated. An experiment is being designed to measure the grain temperature of rough rice stored at various relative humidities. This will be related to change in fungal flora of the rice as determined by plating techniques.

(MQ 2-7 (Rev.))

C. Quality maintenance in storage

1. Heat Damage of Rice. This research project covers the cause and prevention of heat damage in rough rice in relation to off-farm conditioning, handling, and storage in the South-Central States. The free amino acids extracted from rice discolored as a result of infestation by Fusarium chlamydosporium are being investigated and compared with the free amino acids from non-infested rice. A technique involving two dimensional multi-chromatography of extracts purified by the use of a strong cation resin column has resulted in the separation of 22 ninhydrin reactive compounds from infested rice as compared with 17 from noninfested rice. Quantitative differences are also obvious from the inspection of the chromatograms. The presence of furfural or hydromethyl-furfuraldehyde (compounds associated with the Maillard reaction) have not been demonstrated in either extracts from the discolored rice or the cultural filtrates.

(MQ 2-76)

2. Damage and Off-Color in Rough Rice. This new study is concerned with the cause and prevention of damage and off-color in rough rice in relation to off-farm conditioning, handling, and storage in the South-Central States. Inoculation experiments with Aspergillus spp. have been temporarily discontinued. Handling grain heavily infested with these species contaminated the laboratory to such a degree that numerous experiments had to be discarded. Rhizoctonia spp. isolated from Belle Patna rice is being investigated to see if it is a cause of the discoloration being reported in rice by industry. The study will include Bluebonnet 50 to determine if the reported varietal susceptibility of Belle Patna is valid.

(MQ 2-77)

D. Prevention of insect infestation

1. Insecticide Evaluation. A part of the program on insecticide evaluation at Savannah, Georgia, has been charged to rice. Although much of this research is directly applicable, it is not feasible to report only certain portions here, or to include all the information under each of the several appropriate commodity areas. Therefore the entire report is included in Area 13, "Insect Control in Marketing Channels - Cross Commodity."

2. Insecticidal Control. The remainder of the tests were concluded in the series of experiments planned to develop improved procedures for fumigating milled rice in storage. Suitable dosage levels and methods of application were determined for several fumigants for bulk and bagged milled rice and the line project was terminated.

(MQ 1-3)

3. Insecticide Residue Analysis. The overall chemical analytical program at Savannah, Georgia, is reported in Area 13.

4. Nonchemical Control. Laboratory tests have shown that the common internal feeding insects of rough rice can be killed by infra-red radiation at temperatures that are harmless to the rice. Early data suggested that the reproduction of rice weevils and lesser grain borers subjected to sub-lethal radiation was severely limited. An intensive study of the Angoumois grain moth, however, indicate that reproduction of this species was not seriously affected by exposure to infra-red radiation at sub-lethal levels.

(MQ 1-9)

A large scale test was conducted with 3 chemically inert dusts of the silica gel type as protective treatments for rice to prevent insect infestation. They continued to give satisfactory protection until it was necessary to move the rice. At that time they added considerably to the dust problem during the handling of the rice. This could be a serious deterrent to the commercial acceptance of inert dust treatments for grain. The dust did not adversely affect the milling qualities or the germination of the rice.

(MQ 1-19)

5. Insect-Resistant Packaging. These studies at Savannah, Georgia, as with those on insecticide evaluation and insecticide residue analysis, are reported under Area 13.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Objective Measurement and Evaluation of Quality

- Johnson, R. M., and Neustadt, Morris H. 1962. An improved apparatus for the alkali test for differentiating long-grain varieties of milled rice. The Rice Journal 64(10): 8-9.
(MQ 3-12)
- Johnson, Robert M. 1963. A physical method for differentiating certain long-grain milled rice varieties. Cereal Science Today 8(3): 84-90.
(MQ 3-12)
- Primo, E., Casas, A., Barber, S., y Barber, C. Benedito de. 1962. Factores de calidad del arroz. VII. Ensayos selectivos basados en el envejecimiento: Propiedades organolepticas y fisicoquimicas del grano. Publicado en la Revista de Agroquimica y Tecnologia de Alimentos Vol. 2 n° 3, julio-sepbre. 1/
- Primo, E., Casas, A., Barber, S., y Barber, C. Benedito de. 1962. Factores de calidad del arroz. VIII. Caracteristicas fisico-quimicas del almidon y de sus fracciones Su variacion con el envejecimiento. Publicado en la Revista de Agroquimica y Tecnologia de Alimentos Vol. 2, n° 4, oct.-dic. 1/
- Primo, E., Casas, A., Barber, S., Barber, C. Benedito de, Alberola, J., y Pinaga, F. 1962. Factores de calidad del arroz. IX. Influencia de las fracciones proteicas sobre la calidad de coccion. Publicado en la Revista de Agroquimica y Tecnologia de Alimentos. Vol. 2, n° 4, Oct.-dic. 1/
- Primo, E., Casas, A., Barber, S., y Barber, C. Benedito de. 1963. Factores de calidad del arroz. IV. Distribution del nitrogeno en el endospermo. Publicado en la Revista de Agroquimica y Tecnologia de Alimentos, Vol. 3, n° 1, enero-marzo. 1/

Quality Maintenance in Storage

- Schroeder, Harry W., and Halick, John V. 1963. Effects of moisture content, humidity, and length of storage on maintenance of quality in rough rice. Marketing Research Report #598.
(MQ 2-77)
- Schroeder, Harry W. 1963. The relation between storage molds and damage in high-moisture rice in aerated storage. Phytopathology, July, pp. 804-808.
(MQ 2-77)

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Schroeder, Harry W. 1963. Changes in the fungus flora of rough rice after flooding with saline water by Hurricane Carla. Plant Disease Reporter 47: 118. (MQ 2-77)

Schroeder, Harry W. 1963. Orange stain, a storage disease of rice caused by penicillium puberulum. Phytopathology, Vol. 53, No. 7, pp. 843-845. (MQ 2-77)

Schroeder, Harry W. 1963. Effect of the growth of fungi on head rice yields. Proc. of Rice Technical Working Group, February 21-22, 1963, Houston, Texas, p. 31, March. (MQ 2-77)

Schroeder, Harry W. 1963. Two types of rice kernel discoloration caused by fungi. Published in Proc. of Rice Technical Working Group, February 21-22, 1963, Houston, Texas, pp. 30-31, March. (MQ 2-77)

Prevention of Insect Infestation

Tilton, Elvin W., and Cogburn, Robert R. 1963. Field tests of phosphine gas for fumigation of rice. Proceedings Rice Technical Working Group, February 21-22, 1963, Houston, Texas, p. 29, March 1963. (MQ 1-3)

Cogburn, Robert R., and Tilton, Elvin W. 1963. Using phosphine to protect stored grain from insects. Published in Agricultural Marketing, Vol. 8, No. 3, p. 3, March 1963. (MQ 1-3)

Tilton, Elvin W., and Schroeder, Harry W. 1963. Infrared heaters (nonchemical) may protect stored grain from insect damage. Published in Agricultural Marketing, Vol. 8, No. 1, January 1963. (MQ 1-9)

FEED AND SEED - MARKET QUALITY
Market Quality Research Division, AMS

Problem.

Feed and seed may suffer damage or deterioration in quality from insect attacks, from microorganisms, and from normal metabolic changes. Insect infestations are a major problem with feed and do much damage both to the individual components and to the mixed product. Seeds are also subject to insect damage. Quality determination of seed is essential to modern agriculture and orderly marketing. Important quality factors include genetic purity, germination, vigor, weed-seed content, disease-organism infestation, and mechanical purity. Methods of determining seed quality are outdated, requiring much time, tedious work, and 1 to 6 weeks for completion of germination tests. Because seed is an important item in interstate and international channels of commerce, methods of testing for quality should permit duplication of results by laboratories in different states and countries. Stored seed is subject to deterioration with respect to germination and vigor. Deterioration caused by fungi, bacteria, and metabolic changes within the seed is influenced by storage temperature, relative humidity, gases, and time in storage. Research is needed to learn the biochemical changes that take place during seed germination, to mechanize and simplify the methods of testing seeds, and to improve the storage life of seeds.

Development of rapid, simple tests for determining the quality of feeds is essential as new sources of proteins, vitamins, and other additives are mixed with animal feeds. More information is also needed so that feedstuffs can be stored with a minimum of loss in quality.

USDA PROGRAM

The Department has a continuing long-term program involving chemists, botanists, seed technologists, plant physiologists, and plant pathologists engaged in both basic and applied research on quality evaluation and quality maintenance of seed. This research is

conducted at Beltsville, Maryland; Raleigh, North Carolina; and at College Station, Texas, and by research contract with experiment stations of Mississippi, Iowa, and Oregon.

A grant with Israel Institute of Technology, Haifa, Israel, provides for a study to develop tests for nutritive value of cereal grains and feeds. Its duration is 4 years, 1960-1964, and involves P. L. 480 funds with a \$103,785 equivalent in Israeli pounds.

A P.L. 480 grant with Instituto Biologico, Sao Paulo, Brazil, provides for a study of substrate moisture levels for germination testing of agricultural seeds. Its duration is 5 years, 1962-1967, and involves \$31,016 equivalent in Brazilian cruzeiro.

A P.L. 480 grant with Rijksproefstation voor Zaadcontrole, Bommenhaven 1, Wageningen, The Netherlands, provides for a study of the health condition of seeds in commercial channels and development of methods suitable for routine testing for seedborne organisms. This project has been approved but work will not be started until about January 1, 1964. The duration of the project is for 5 years and the total grant is the equivalent of \$55,777.

The Federal scientific effort devoted to research in this area totals 8.5 professional man-years, of which 3.5 man-years are by research contract.

Work terminated during the period included studies on classification of seedlings produced in laboratory germination tests from seeds of southern crops such as cotton, peanuts, velvet beans, soybeans, and lupines (MQ 3-19) and seed blending (MQ 3-8(c)).

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement and evaluation of quality

1. Seed Blending. Seventeen devices were tested for performance in blending seed of similar and dissimilar composition. The principal crop seeds used were soybean, birdsfoot trefoil, sorghum, fescue, and oats. Four batch blenders were evaluated: Nauta mixer, twin shell mixer, double cone mixer, and a rotating drum mixer with the drum mounted diagonally on a horizontal axis. All four blenders gave good results but the size of the lot blended would be limited by the capacity of the blender.

Several types of continuous blenders and devices were used. These made use of columns of baffles, columns of funnels and cones, rotating cylinders, revolving distributors, and commercial seed dividers. Of these devices, the Boerner seed divider produced the best results. One unit designed and constructed under the project provided a uniform and systematic placement of each component into a container. The individual particles and components assumed random arrangement within these small subunits. The results were not entirely satisfactory, but showed considerable promise. This project has been terminated.

(MQ 3-8(c))

2. Seedling Classification and Seed Dormancy. A study of seedling classification of cotton showed that the primary difficulty was infestation of the young seedlings with fungi. Treatment of the seeds in baths with ultrasonic radiation to remove the mold spores had little effect on seedling diseases. Treatment of the seeds with the fungicide, Ceresan M, significantly reduced seedling infection and increased the percentage of normal seedlings. It is recommended that in routine testing of cotton seeds, two parallel tests be made: one test on seeds without any treatment and another on seeds treated with an effective fungicide. A study to determine the correlation between actual germination and electrical conductivity of water in which seeds had been soaked did not yield encouraging results.

Texas needlegrass seeds are extremely dormant and possess enveloping structures that interfere with the penetration of water. Also, a relatively high percentage of the true seeds are too immature to germinate. A study of this species showed that a very delicate balance of moisture and aeration is necessary for reasonably good germination. The most satisfactory method found to overcome dormancy consisted in orienting the seeds on the substratum in such a way that only the bases of the seeds were in contact with the moist substratum and the apical end extended into the air. Several temperature combinations gave satisfactory germination when the seeds were oriented as indicated above. When the glumes were removed the seeds germinated readily under a variety of conditions.

(MQ 3-19)

3. Mechanization of Purity Analysis. Work under this project, begun last year, has resulted in the designing and construction of models of several laboratory size machines which will reduce

the time and tediousness of certain operations in making purity analyses of seeds. The equipment has been tested by unbiased workers and demonstrated before a national convention of official and commercial seed technologists. Two machines have been approved for routine laboratory use and construction specifications and plans will be made available at an early date. These include (a) a vibrator separator which will separate many kinds of seeds much like the gravity machines in commercial use and (b) an examination station for seeds treated with poisonous chemicals. The latter machine permits the seed to move past a viewing point on a movable belt, controlled by foot switch, and be viewed through a transparent plastic window. Rejected particles are removed with vacuum pickup needles. Development of other machines is proceeding satisfactorily.

(MQ 3-21(c))

4. Rapid Electrical Methods for Determining Moisture Content of Seeds. A meter has been developed adapting a commercial electronic moisture meter for determining moisture in light and chaffy seeds. The meter is being tried on Kentucky bluegrass, perennial ryegrass and other grass seeds. It shows promise but will require much more testing.

(MQ 3-23)

5. Seed Metabolism. Procedures were developed for isolation of RNA and DNA from peanut cotyledons at various stages of germination. These nucleic acids were studied by means of column chromatography and density gradient fractionations as well as by base ratio analyses. A major shift in the nature of the high molecular weight RNA component was noted between the first and second day of germination. Similar experiments with P^{32} -labeled nucleic acid demonstrated that the germinating cotyledon actively synthesizes all nucleic acid components. Studies on enzyme development with germination demonstrated that enzyme formation in the cotyledon proceeds in the absence of the embryo and proceeds even when embryo germination is completely inhibited.

(MQ 3-32)

6. Determining the Purity of Certain Grass Seeds. Acetone, ethyl alcohol, methanol, hexane, and carbon tetrachloride were evaluated as media for separating pure seed and inert matter of dallisgrass seed and bahiagrass seed on the basis of specific gravity. Germination tests were made to determine the effects of these solvents on germination. None of the compounds had a significant effect on germination of bahiagrass seed at the 99

percent confidence level. Ethyl alcohol, methanol, and acetone significantly lowered the germination of dallisgrass but the other solvents did not. Of several liquids tested for separating seeds by specific gravity, ethanol and methanol were significantly better. Surface tension, especially with kerosene, was found to be an important factor.

(MQ 3-39)

7. Hay Moisture. This new project covers research to develop an accurate and rapid method for determining the moisture content of grass and legume hay for use in routine testing. Twenty-six samples of alfalfa hay were measured by a compression device using a newly-designed large sample holder. An electrode plate designed to fit this 5-inch cylinder sample holder consisted of a dish with four stainless steel pins mounted 2 inches apart on a 1.414-inch radius from center of dish. The holder is capable of holding from 250 to 350 grams of dry hay. The moisture content of these samples varied from 11.9 to 29.0 percent moisture as determined by a forced air oven. The correlation between the meter reading and oven was very good (0.97) for these 26 samples. The standard error of estimate was ± 1.03 percent.

(MQ 3-41)

8. Development of Seed Germinator. Research was started to develop an automatic alternating temperature seed germinator for use in routine testing. The experimental unit was equipped with thermistor activated temperature controllers in order to obtain closer control of temperatures than could be obtained with gas-filled bulb thermostats. Any two temperatures desired from 10° C. to 35° C. can be selected simply by positioning a rotary switch. In performance studies, temperatures were controlled to $\pm 0.5^\circ$ C. Relative humidity was maintained above 95 percent except for a brief period when switching from the high to low temperature cycle. The temperature changes from low to high are made in approximately 40 minutes and from high to low in approximately 1 hour. The problem of obtaining more uniform lighting in the box will be under study the coming year. Germination tests indicate lighting is sufficient but distribution is poor and trays must be rotated daily.

(MQ 3-48)

9. Cereal Grains and Feeds. Research aimed at the development of a rapid, simple test for protein nutritive value of cereal grains and feeds is being conducted by Technion Research and Development Foundation, Ltd., Haifa, Israel, under a P.L. 480

grant. Soybeans, rice, wheat, peanuts, and cottonseed meal were placed in storage under different conditions of temperature and humidity. Any successful method must measure quality of commodities after storage under both favorable and unfavorable conditions. The nature of the project makes it possible to study both quality maintenance and quality measurement. Analysis of all foods has been carried out according to AOAC methods and by additional methods, including feeding experiments with rats and miscellaneous chemical and physical tests.

Twelve amino acids were determined microbiologically in the various stored commodities and enzymatic releases of methionine, lysine and tryptophane were determined in eight foods. Optimal conditions for determining glutamic acid decarboxylase activity in soybeans, chickpeas, wheat, and rice have been established. A method, capable of standardization, for protein dispersion from soybeans, peanut meal, cottonseed, and chickpeas containing globulin-like proteins has been developed. Some difficulty has been experienced in obtaining random groups of uniformly developing rats for the feeding experiments but the variation has been reduced by selection of mothers for several characteristics and by using rats whose ages differ by no more than 2 days.

(A10-AMS-7(a))

10. Moisture Levels for Germination. A P.L. 480 grant was made to the Instituto Biologico, Sao Paulo, Brazil, for the study of substrate moisture levels for germination testing of agricultural seeds. The principal accomplishments reported by the Instituto Biologico are: (a) The optimum moisture level for germination is not always optimum for future growth of the seedling, (b) seedling classification must be taken into consideration in the study of moisture relationships, (c) water was found to be dependent on weight of seeds of a similar kind and not on the number of seeds involved, (d) a procedure was developed for holding soil as a substratum at three different uniform moisture levels, thus providing a basis for evaluating tests made on other substrates.

(S3-AMS-2(a))

11. Health Condition of Seeds. A P.L. 480 grant with Rijksproefstation voor Zaadcontrole, Bommenhaven 1, Wageningen, The Netherlands, provides for a study of the health condition of seeds in commercial channels and development of methods suitable for routine testing for seedborne organisms. This project has been approved but work will not be started until about January 1964.

(E19-AMS-11(a))

B. Quality maintenance in storage

1. Quality Maintenance of Corn in Storage. The results of these studies indicate that corn seed with a moisture content of 8 percent or less, can be stored at 68° F. and below at levels of oxygen ranging from 0 to 100 percent, without a severe reduction in germination or growth of seedlings. Methods of chemical analysis were adapted to study injuries on very dry corn in storage caused by oxygen.

In general, peroxide formation was not directly related to the storage life and vigor of the seed. Assays for carotenoids showed a decline of pigments during storage which apparently was correlated with the amount of oxygen in the storage atmosphere. This loss of pigment appeared to be one of oxidation and was not correlated with seed moisture. No significant variation was revealed between the total fat content of seeds of different moisture contents stored at different oxygen levels. Results of phosphorous analysis were disappointing due to lack of suitable methods for analyzing the small fractions involved. Studies of conductivity of seed leachates indicated that results of these tests might be more reliable in the general assessment of stored grain rather than as tests for germination.

Respiration studies of very dry corn revealed extremely low rates of carbon dioxide production. These results and other corroborative evidence could suggest that the carbon dioxide obtained was not the result of enzymatic respiration.

(MQ 2-34)

2. Deterioration of Grass Seed. Year-old seeds of seven kinds of grasses received from seedsmen were plated out on salt-malt extract agar suitable for the growth of storage fungi. Sixteen species of *Aspergillus* were obtained in pure culture and identified. Some of these fungi will be used to inoculate grass seeds that will be stored for several months at 16 combinations of temperature and relative humidity. These seeds will be used to study the progress of infection and pathological histology.

The moisture contents of 38 samples of grass seed harvested in 1962 ranged from 7.94 to 9.51 percent (wet weight basis). Most of these samples were found to be infected by species of *Aspergillus* that are reported to infect grain whose moisture is above 13 percent.

No significant differences were observed between the mold flora of 10 samples of spotted wheat and that of 4 nonspotted (check) samples. Cultures of a number of pathogenic species of *Helminthosporium* and *Fusarium* are being evaluated to determine whether one of them may produce an inhibitory substance that can be used in developing a vigor test for seeds and seedlings.

(MQ 2-62)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Objective Measurement and Evaluation of Quality

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Hart, Joe R., and Golumbic, Calvin. 1962. A comparison of basic methods for moisture determination in seeds. Proc. Internat. Seed Test. Assn. 27(4): 907-919. (MQ 3-23)

Marcus, A., Feeley, J., and Shannon, L. M. 1963. Preparation and properties of γ -methylene glutamic acid. Arch. Biochem. Biophys. 100, 80. (MQ 3-32)

Marcus, A., and Feeley, J. 1962. Nucleic acid changes in the germinating peanut. Biochem. Biophys. Acta 61, 830. (MQ 3-32)

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MARKETING FACILITIES, EQUIPMENT AND METHODS
Transportation and Facilities Research Division, AMS

Problem. Differences in varieties of individual field crops and in the environments of producing areas where they are conditioned and stored, together with advancing techniques in cultural and harvesting practices, require new or modified marketing facilities, equipment, and methods. Such changes are essential to the efficient and economical handling, conditioning, and storing of these crops and to maintaining their quality. There is a need for improved designs for facilities based on functional and structural requirements, which will expedite the movement of commodities into, within, and out of the facility. There is also a need for handling and conditioning equipment which will minimize labor and other costs. More knowledge is needed of the relative efficiency of various handling and conditioning methods so that improved or revised methods and equipment can be developed to perform necessary operations.

USDA PROGRAM

The Department has a long-term program involving agricultural engineers and industrial engineers engaged in both applied and basic research on, as well as application of known principles to, the solution of problems of handling, storing, and conditioning field crops in marketing channels. Grain aeration and drying research is carried out at Manhattan, Kans., on wheat and grain sorghum; at Lafayette, Ind., on corn; in laboratory and pilot-scale facilities and in commercial storages; in cooperation with the Agricultural Experiment Stations of Kansas and Indiana and with grain storage firms. Cooperative research on grain is supplemented by research contracts with the Airfoil Impellers Corporation, College Station, Tex., and the Purdue University Agricultural Experiment Station, Lafayette, Ind. Research on the design of grain storage structures is conducted at Washington, D. C., with field studies providing the basis for selecting capacity and type of operation. Research on the handling of grain in country elevators and terminal storages is conducted by the Manhattan, Kans., field office in cooperation with the Kansas Station. Studies of grain storage in CCC bins are conducted at a research bin site at Watseka, Ill. Studies on the handling, drying, aerating, and storing of rice are conducted at Beaumont, Tex., in cooperation with the Texas Agricultural Experiment Station and at commercial facilities in Texas, Arkansas, Louisiana, and Mississippi.

The Federal effort devoted to research in this area totals 12.2 professional man-years: 5.0 to grain aeration and drying; 0.8 to the design of grain storage structures; 0.9 to the handling of grain in terminal storages; 1.5 to studies of grain storage in CCC bins; 2.0 to the handling, drying, aerating, and storing of rice; and 2.0 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATING PROGRAMS

A. Grain Aeration and Drying

1. Drying. At Lafayette, Ind., additional laboratory tests confirmed that artificial drying at air temperatures above about 140° F. changes the hygroscopic properties of corn and that corn dried at such temperatures supports a higher equilibrium relative humidity than corn of the same initial moisture dried with room air. Results of these tests indicate that, to prevent excessive mold development and spoilage during storage, artificially dried corn with its higher interseed relative humidity should be stored at a moisture content 1/2 to 1 percent lower than naturally dried corn.

A quick and inexpensive process--and a device for performing the process--has been developed for determining the equilibrium relative humidity of a sample of corn which provides an objective measurement of: (1) The suitability of corn for wet milling and other commercial uses, and (2) overheating of the corn during artificial drying. Development of this process represents a substantial "break through" in providing a satisfactory measure of the suitability of corn for processing and storage and can affect savings to the industry amounting to many thousands of dollars annually. Applications for public patents on both the process and the device are being filed.

In laboratory tests the milling quality of corn dried with the concurrent flow method was slightly better than for that dried by the other two methods. Also, corn dried by the concurrent flow method had 27 percent checked kernels as compared to 49 percent in corn dried by the crossflow method.

Drying methods for field-shelled corn were further evaluated in 19 field tests in the fall of 1962. The relation of the drying treatment to the quality of the corn for commercial uses was summarized for tests extending over three seasons.

The temperature of corn reached during drying was found to be the controlling factor in milling quality. However, corn temperatures remained substantially below the drying air temperatures in the field tests. For example, corn dried at an air temperature of 140° F. reached 119° F., and at an air temperature of 190° F. it reached 149° F.

The starch yield was reduced less than 2 percent in the drying tests at 140° F and 190° F. At 240° F. and 290° F. the reduction in starch yield for the three test years averaged considerably higher. The average amount of protein mixture in the starch after separating the gluten and starch showed no adverse effect with drying air temperatures of 140° F. and 190° F., a slight increase at 240° F., and more than a threefold increase at 290° F. Slightly better milling characteristics were observed when drying was started

with corn at an initial moisture content of 20 percent rather than at 30 percent. The drying method--batch or continuous-flow--made little difference in any of the quality factors measured.

The susceptibility of the corn kernel to breakage when handled and the incidence of stress cracks in the endosperm were continued as measures of physical changes in the corn caused by drying. Shelled corn dried with heated air (140° to 240° F.) was two to three times more susceptible to breakage than the same corn dried with unheated air. Corn harvested at initial moistures near 30 percent broke easier than that harvested at 20 percent moisture.

Some of the corn dried with air at 290° F. had a puffed appearance and reduced test weight. The crowns of the puffed kernels were almost completely removed in the breakage tests, revealing cavities in the endosperm.

Stress cracks accounted for much of the increase in breakage due to drying. Drying speed was the most significant factor in stress crack development. The total amount of drying as well as the drying speed appears to affect stress crack development. Stress crack evaluation is useful not only in detecting corn that has been dried rapidly, but also aids in predicting increases in foreign material that may be expected from breakage during handling.

A report on breakage and stress cracks in artificially dried corn was prepared and publication is expected in October 1963.

The work under a research contract with Purdue University wherein the first moisture-sensing control system for continuous-flow dryers was designed and tested has been completed. This control system can be readily adapted to conventional continuous-flow dryers and the capacity of the dryers is not changed by the addition of the control system as compared to that when dryers are manually controlled. The use of a digital computer for simulating the drying process and control system proved to be an excellent method for system analysis. The speed achieved by the simulation model allowed the investigation of four control systems which would have been impossible to accomplish in the available time by actual testing of the systems. The simulated drying of 528,000 bushels of grain representing 4,400 hours of drying time was accomplished by computer analysis. Steps have been taken to initiate patent applications on the control systems.

At Manhattan, Kans., research was initiated in July 1963 to develop a satisfactory low cost system for unheated air drying of grain stored in up-right deep bins (silos). This system is intended to accomplish the small amount of drying needed to condition grain having a moisture content of 1 to 3 percent too high for safe storage. Available information and preliminary tests indicate that a crossflow system, providing horizontal air movement in the stored grain, can be used for this purpose. Such a system can provide adequate airflow--2½ to 5 times the airflow needed for aeration --to accomplish the necessary drying.

2. Aeration. At Manhattan, Kans., field studies were continued in commercial storages, both flat and upright.

During poor harvesting weather in June 1962, thousands of bushels of "tough" new wheat, having an average moisture content of 14 to 16 percent, were received and stored in upright concrete bins. In one test, non-aerated "tough" wheat went out of "condition," becoming musty and showing serious damage. The loss in market value amounted to as much as 40 cents per bushel or a loss to the storage owner of approximately \$800 per 2,000-bushel railroad car. In a companion test, wheat having 14.6 percent moisture stored in June was turned once each during the summer, fall, and winter and aerated after each turn. In December the average grain temperature was 42° F. and in May 1963 the moisture content was 0.7 percent lower and the wheat graded No. 1 Hard Winter with no loss in market quality.

Field tests were made in upright storages using automatic fan control schedules to limit fan operation to hours of low solar energy accumulation. Results from these tests indicate longer fan operation time being required to complete a cooling stage during periods of low solar energy accumulation than under ordinary aeration schedules. This was due to less evaporative cooling and a smaller reduction in the moisture content of the grain.

The emptying of flat storages, included in field studies, in which the grain had not been moved for periods of from several months to several years provided an opportunity to study the effects of aeration. Some grain spoilage was observed near and over aeration ducts, both solid and perforated, and on some concrete floors. The total amount of grain loss from these causes was extremely small, however, compared to the total quantity of grain stored in a flat storage building, up to 750,000 bushels and even more.

Field studies were continued with both wheat and grain sorghum in large flat storages with the main emphasis on developing suitable methods of controlling the operation of aeration systems to maintain the market quality of the stored grain. Satisfactory results were obtained in tests where a single automatic control was used for controlling the operation of 14 fans in one large storage. Four hundred hours of fan operation during January and February reduced the temperature of stored grain sorghum from 67° to 37° F., a reduction of 30 degrees.

In Indiana, two-year tests comparing year-round aeration and aeration limited to the fall and winter months for shelled corn had to be terminated when approximately 3/4 of the storages included in the study were unloaded. Therefore, this study was terminated.

In Texas, field studies have been terminated and a final report is being prepared for publication. Personnel formerly conducting this research have been transferred to research on peanuts.

At College Station, Tex., work under a research contract was continued to determine static pressure losses in additional ducts in various sizes, losses from abrupt changes in duct sizes, and to determine the changes in static pressure of air moving through aeration duct perforations and through grain over the duct. The major part of the actual testing work has been completed and the analysis of the data contained in two of the contractor's reports on completed tests has been started.

B. Handling Grain in Country Elevators and Terminal Storages

At Manhattan, Kans., a report, "A Complete-Opening Endgate For Faster Unloading of Grain From Farm Trucks," was prepared and published. A complete-opening endgate, made of plywood, hinged at the top and opening across the full width of the grain body permits a 200-bushel standard farm truck to be unloaded at the elevator in 53 seconds, with no shoveling required. A small sliding endgate can be built into the full-width endgate for use in unloading grain at the farm. Estimated cost of materials, in early 1963, to build the endgate, exclusive of the small sliding gate, was \$23.

The study of grain cooling during turning operations and during extended periods was continued for a second year. During the second year the grain was not turned and the average temperature of the grain at the center of the bin increased by only 10 to 12 degrees. However, the grain 2 feet in from the wall increased from 36° F. in January to 78° F. in August, an increase of more than 40 degrees.

Comparative tests of various liner materials for grain spouts were continued. One material under test had handled about two and one-half times more grain than currently-used materials. When last inspected, the better material had handled 380 carloads of grain as compared to a maximum of about 150 carloads for commonly-used materials. This better material is still under test.

C. Design of Grain Storage Structures

Work was continued by the Washington office on the use of the queuing theory to determine optimal capacities of truck receiving systems for commercial grain elevators. Additional field studies were conducted during the 1962 wheat harvest in Kansas and Nebraska to collect additional data on truck arrivals and service patterns. The data obtained verified the results from previous field studies. About 20 percent of the total wheat received at the elevators during the harvest period arrived in only one day and although the elevators were open about 16 hours a day, more than 10 percent of a day's receipts arrived in one hour, usually late in the afternoon. During that hour, trucks arrived in a random manner; but 20 percent or more of the hourly receipts may arrive in a 5-minute period.

The service times for receiving trucks were studied for crew sizes of 1 to 4 men at the scale and 1 to 3 men at the dump pits. Because of the different

types of trucks used and for other reasons, service times varied considerably. For example, at one elevator studied the time to dump a truck ranged from 1 up to 6 minutes although the same crew was always used. Both arrival and service patterns followed statistical distribution patterns often used in theoretical waiting line analysis. From these distribution patterns a method of simulated sampling--Monte Carlo Method using an electric computer--was used to determine truck waiting times for receiving units of low, medium, and high capacity. Results of this simulation were developed into charts which show, for example, average and maximum truck waiting time for different daily arrival rates. It was found that waiting times increase rapidly when the daily arrival rate goes above 50 to 60 percent of the daily potential service rate.

Waiting times were converted into waiting costs; these costs were added to ownership and operating costs to find the most economical range of operation for the three capacities of receiving units. For example, it was found that a country elevator of medium capacity with a 2-man crew at the scale and another 2-man crew at the pit was the most economical where from 600 to 1,450 truckloads are received each harvest season.

Several simplified, approximate methods for determining waiting times were developed. Also studied were methods which could be used by elevator operators in improving truck receiving operations, such as: (1) Evening out the arrival pattern by paying a premium for dry grain arriving before Noon; (2) providing plenty of room between scales and dump driveway for waiting trucks; (3) providing one-way traffic across the scale with the driver always on the side toward the scale and the office; and (4) using portable auxiliary unloading equipment, such as pneumatic conveyors, at times of peak receipts.

D. Studies of Grain in CCC Bins

At Watseka, Ill., studies were continued in standard USDA aerated bins to develop more satisfactory methods of fan operation for minimizing the moisture increase in the surface layers of stored corn during the late fall and winter months. A continuously-operated fan caused a slight wetting of the surface corn during the winter months but this corn dried during the spring and summer. Since airflow is downward through the corn a layer of wet corn develops deeper in the bin. Various methods of fan operation are being studied to lessen this moisture increase.

In two tests, started in 1959, fans have been operated each year as exhausters (air downward) from September to December, stopped until February, then reversed and operated as blowers (air upward) until September. Samples drawn from the upper 8 feet of corn in these bins showed an average increase of only about 1 percent in total damage after 3 years in storage. In comparable test bins with the fans operating continuously as exhausters the increase in total damage was about 2.5 percent.

In two tests started in 1960, fans were operated each year as exhausters from September to December or January, stopped until February or March, then operated as blowers until September. Corn in the upper 8 feet in these test bins showed an average increase in damage of less than 1.0 percent after 2 years of storage.

In 1962, a test was started to investigate the effect, on corn moisture content, of warming stored corn which had been cooled during the winter. Results showed that a fan delivering 100 cfm, and operating continuously, warmed the grain from an initial temperature of 30° F. to 80° F. At the same time corn moisture in the lower portions of the grain mass increased slightly more than 1 percent.

A study in 8 aerated flat storages was initiated in the fall of 1962 to expand a previous study which had indicated that increases in total damage, after 21 months of storage, were about 25 percent less when the fan was operated as a blower as compared to one operated as an exhauster. Fans on four of the test storages were operated as exhausters and on the remaining four as blowers. Corn samples obtained monthly indicated slightly less moisture build-up during winter months in the storages where fans operated as blowers. Corn moisture levels were also lower where fan operation was controlled by a humidistat-thermostat as compared to control by time clock. Temperature changes in the corn were nearly uniform along the length of the storage whether the fan was operated as a blower or an exhauster. These studies are still underway and samples will be obtained in October 1963 to measure any changes in market quality of the corn.

E. Handling, Drying, Aerating, and Storing Rice

1. Handling. A study of handling and operating methods and equipment in commercial rice dryers in Texas, Arkansas, and Louisiana was initiated by the Beaumont, Tex., office during the year. Visits were made to several dryers in Texas and Louisiana to obtain information listed on a questionnaire approved by the Bureau of the Budget. A preliminary study of handling methods and use of labor and equipment during rice drying operations was made at selected rice dryers. Data obtained have not been analyzed at this time.

2. Drying. Tests of rice drying procedures were continued during the harvest seasons of 1962 and 1963 in the experimental pilot-scale dryer at the Rice-Pasture Experiment Station, Beaumont, Texas.

Tests run in 1962 indicated that heating rice in the dryer to 120° F. during the first pass and reducing temperatures below 120° F. for succeeding passes was a better method than drying the first pass at a temperature below 120° F. then increasing the drying air temperature for each succeeding pass until 120° F. was reached during the final pass. Consideration was given to milling yield, drying time and fuel consumption in comparing these two methods.

Further tests were run during the 1963 harvest season to compare the effect of throughput rates on milling yield, drying time and fuel consumption. Data from these tests have not yet been analyzed.

A small-size dryer (50-pound capacity) was designed and built to simulate the drying action of full-size continuous-flow, heated-air dryers. This dryer is used to provide extra replications of procedures tested in the larger dryer and is expected to speed up the obtaining of usable information on drying procedures.

3. Rice Aeration and Storage Tests at the Rice-Pasture Experiment Station

A study of aeration of dry rice during a 5-month storage period (November 1962 to April 1963) was made to determine how different operating procedures contributed to changes in the moisture content of rice. Loss of moisture varied from 0.3 percent in stored rice exposed to single stage cooling to 1.7 percent in rice exposed to continuous fan operation when atmospheric conditions were favorable for moisture removal. This study indicated that shrinkage in rice due to loss of moisture need not be excessive during winter storage if unnecessary fan operation is avoided.

The study of aeration for maintaining the quality of undried (green) rice was continued. With an aeration rate of 1/2 cfm per barrel, rice (TP 49 variety) with 19 percent moisture remained at grade No. 1 for 22 days when the ambient temperature averaged 68° F.; rice (Nato variety) with 23 percent moisture dropped from grade No. 1 to No. 2 in 2 days when the ambient temperature averaged 80° F. More tests must be run in order to determine the relative importance of moisture content, ambient temperature, and variety of rice in predicting a safe storage time for green rice. Doubling the airflow rate, from 1/2 cfm up to 1 cfm per barrel, increased the safe storage time for two batches of rice (Bluebonnet 50) about 40 percent.

The study of rice stored in bins covered with special paints for reflecting solar heat was completed in January 1963. This study indicated that the use of radiation-resisting paint would be beneficial for any rice storage buildings having direct exposure to the sun in at least two ways: (1) To maintain stored rice at a cooler temperature; and (2) to maintain a cooler temperature for personnel who must work in the headspace above the rice.

A report of this study has been prepared and at the end of the year was being cleared for publication.

PUBLICATIONS REPORTING RESULTS OF USDA AND
COOPERATIVE RESEARCH

Grain Aeration and Drying

Smith, Lloyd L., Grain Aeration Systems - Their Uses, Design, and Operation. Paper presented at the Association of Operative Millers Meeting, Winston Salem, North Carolina, October 1962.

Hutchison, R. S. and Allen, W. S., 1963. Your Aeration System - A Comprehensive, Usable, Fool-Proof Method For It. Grain Trade Buyers Guide, Vol. 19, 1963.

Handling Grain in Country Elevators and Terminal Storages

Graves, A. H., 1963. A Complete-Opening Endgate for Faster Unloading of Grain From Farm Trucks. Marketing Bulletin No. 23.

COOPERATIVE MARKETING
Marketing Division, FCS

Problem: Farmers continue to expand their use of cooperatives in marketing the products of their farms. In light of the rapid and complex changes taking place in technology and in market organization and practices, research is needed to help farmer cooperatives and other marketing agencies perform needed marketing services both more efficiently and more effectively. Farmer-directors, managers and others, including the public, need more information to assist in making decisions on how cooperatives can maintain and strengthen the bargaining power of farmers, increase efficiency and reduce costs of marketing, and better meet the needs of our mass distribution system for large quantities of products on a specification basis.

Farmer cooperatives are an important part of the distribution system and represent a major potential for meeting farmers' marketing problems in our modern, dynamic system. They are organized and operated to increase farmers' net income. However, cooperatives face many problems in achieving this goal. Cooperatives must find ways to consolidate volume, for example, through internal growth, merger, acquisition or federation, to strengthen their market position and meet the needs of mass merchandising. Ways must be found to reduce costs by increasing efficiency through improved operating methods, better organization and management, and more use of new technologies.

USDA PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. Studies are made on the organization, operation and role of farmer cooperatives in marketing. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms. The work is centered in Washington, D. C. Many of the studies, however, are done in cooperation with various State Experiment Stations, Extension Services, and Departments of Agriculture.

The number of Federal professional man-years devoted to this research totals 3.2, of which 1.9 man-years relate to work on grain, 1.0 on feed, and 0.3 to seed.

A. Grain

1. Coordination of marketing. A case study was completed which recommended the merger of two local cooperative elevator associations in Iowa. A study is underway on the feasibility of two large regional cooperatives in Iowa uniting to better and more efficiently serve the producers. A study of the operations of a local cooperative elevator in Virginia was completed and recommendations made for change and improvement. A similar study is underway of a regional grain cooperative in Illinois. A case study is underway on the economic feasibility of a large regional farm supply cooperative in Tennessee, setting up a marketing program for soybeans including the operation of local elevators and possibly a processing plant. Work is being carried on with the Agricultural Experiment Stations in the South in studies of grain marketing problems that are peculiar to their area.

2. Cost and efficiency of operations. A study on cost, volume relations at country elevators in the Spring Wheat Area has been completed and copies of the report distributed. A report has been completed on the economics of flat storage at Kansas country elevators in cooperation with Kansas State University. A study of the economics of grain bank operation is almost complete. This is a joint study with the Economic Research Service and is being done under contract with Purdue University. A case study analysis, made of inventory controls, practices and responsibilities at regional grain cooperatives, showed a great deal of variation in the practices and controls being used.

3. Improving operating methods. The accounting problem for cooperative elevator bookkeepers has been revised and used in three schools in the past year. An advanced problem has been designed and will be used in one school in October. The annual analysis of the financial status and operations of the regional grain cooperatives was continued. These organizations are handling an increasing proportion of the off-farm movement of grain with terminal and subterminal facilities at some 130 strategic locations around the country. Many of the newer facilities have been river or port houses and several cooperatives own a sizable number of barges.

B. Rice

1. Rice storage. Louisiana State University, the contractor, continued to evaluate costs and other economic considerations in drying and storing rough rice in on-farm and off-farm facilities during three seasons, 1959-60 through 1961-62. Preliminary findings based on a partial analysis of the data show that (1) costs of drying and storing rough rice vary with type and size of facility and the extent to which capacity was utilized; (2) the value of rice following drying and

storing varies widely among individual facilities of the same type; (3) the value of rice following drying and storing varies little between the multipass and stationary type units; and (4) off-farm commercial driers tend to perform better on grade, and off-farm driers on milling yield.

C. Farm Production Supplies

1. Feed distribution. Work continued on studies of the feed financing operations of cooperatives. A study of broiler and turkey feed financing of nine cooperatives was completed and a report prepared for publication. Principal findings were reported last year. A study of the egg and replacement pullet feed financing operations by seven large cooperatives neared completion. It indicated that (1) egg and pullet feed financing by cooperatives has not developed at the same rate or magnitude as for broiler and turkey feed; (2) most of the egg and pullet feed was financed on a secured note basis, rather than on a contract basis; (3) losses incurred by the cooperatives through egg and replacement pullet financing plans were insignificant; (4) proven credit practices in selection of growers and careful selection of production areas near feed mills and egg assembly points enabled associations to adjust to changing conditions and operate financing programs most efficiently; and (5) associations with rather complete coordinated production and marketing services realized greater stability and feed volume through their financing programs than those with the least integration. A similar study of the financing of livestock feed by selected cooperatives is underway.

Work was started on an analysis of bulk feed relay depots or transfer stations operated by cooperatives in selected areas of the United States. Emphasis will be placed on type of facilities and practices employed; operating costs; the feasibility of this distribution system compared with other existing systems; and the possible effects this type facility or system will have on continued use of present manufacturing and distribution facilities.

A study was initiated on the operations of local farmer buying groups purchasing feed ingredients in Illinois. This appraisal, being done under contract, will determine the organization of such groups, practices followed, costs involved in their operation, extent of unpaid resources used, and sources and amounts of savings to their members. It also will appraise problems and limitations of such groups and their implication to other cooperatives and firms handling feed.

Limited work was continued on an analysis of methodology for determining the market potential and future trends for various types of commercial feeds in specific areas of the United States.

2. Bulk handling of seed. Work was started on a study of the bulk receiving, distribution, and transportation of seed. Objectives of the study are to determine types and costs of bulk facilities and equipment used, advantages and disadvantages or limitations, and possibilities for further development of bulk handling. Data will be obtained largely from selected wholesale purchasing cooperatives in the East and marketing cooperatives in the West.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Grain

- McVey, D. H. Fall 1962. Grain Co-ops Help All Grain Farmers. Article in Co-op Grain Quarterly.
- McVey, D. H. 1963. Regional Grain Report 1961-62. FCS Service Report 64.
- McVey, D. H. Jan. 1963. Grain Co-ops Help Hometowns Grow. Article in News for Farmer Cooperatives.
- McVey, D. H. 1963. How Grain Co-ops Help Main Street. Article in Farmers Union Herald, Feb. 4, 1963.
- McVey, D. H. Mar. 1963. Grain Co-ops Help Hometowns Grow. Article in Grain Producers News.
- Yager, F. P. 1963 Country Elevators--Cost Volume Relations in the Spring Wheat Belt. FCS Service Report 63.
- Yager, F. P. Accounting Exercises for Cooperative Elevator Bookkeepers. Kansas - 1 school; Oklahoma - 1 school; Texas - 1 school.

ECONOMICS OF MARKETING
Marketing Economics Division, ERS

Problem. Most agricultural processing industries are experiencing rapid and drastic changes in their market organization and practices. These changes are affecting both farmers and consumers. Research is needed to keep abreast of such changes and to indicate their probable consequences. There have been substantial advances in recent year in increasing efficiency and reducing costs through adoption of new technology in producing, assembling, processing and distributing farm products. However, for producers and marketing firms to remain competitive, additional information is needed on margins, costs, economies of scale and efficiencies possible in the marketing of farm products.

USDA PROGRAM

The Department has a continuing long-term program of economic research relating to grain and forage crops. The research involves economists and personnel with dual economic and technical training and is carried out at Washington, D. C., and field offices in Albany, California; and Peoria, Illinois, and in cooperation with State Agricultural Experiment Stations in a number of States. The grain and forage phases of the research involve 16.4 Federal professional man-years of which 3.0 are studying market potentials; 1.3, merchandising and promotion; 3.0 transportation and storage; 0.2, product quality; 5.4, costs, margins, and efficiency; 1.0, structure, practices and competition and 2.5, information and outlook.

REPORT OF PROGRESS FOR U.S.D.A. AND COOPERATIVE RESEARCH

A. Market Potentials for New Products and Uses

1. Adhesives have traditionally been farm derived products but synthetics have taken more and more binding jobs away from them. Study of technical and economic factors indicated that farm derived adhesives have many characteristics that are definite advantages, such as low cost, ready availability, nontoxicity, and ease of handling among others. Nevertheless, farm produced raw materials need to be modified to give them more of the characteristics of the synthetics so they can compete more effectively. The molecular structure of starch and protein glues needs to be modified to make them stronger and more water resistant. Work is also recommended on hot melts based on starch to improve this adhesive's method of application, tack, toughness, solubility in organic solvents, and reduced sensitivity to water.

Such hybrid adhesives would be a boon to the construction industry, among others. Particle board is made by combining sawdust, small wood particles and 30 percent adhesive binder (now mostly synthetics) under pressure. A tough, moisture resistant starch hybrid replacing more expensive synthetics adhesives would considerably lower manufacturing costs.

2. Research is underway to determine the possibilities through freezing for reducing marketing costs for bread which have increased rapidly over the past 15 years. The first step in appraising the feasibility of widespread adoption of freezing has been a survey of about 500 bakers to collect information on bakery operations and the present and probable role of freezing. Nearly 40 percent of the bakers currently are freezing some of their production. The outlook for various uses of freezing for bakery products appears to be one of continuing growth. Many bakers see it as a means of increasing sales by offering a wider variety and fresher quality products at all times at lower cost than without freezing. Other factors favoring increased use of freezing are: (1) The increased use of frozen foods in general, (2) freezing enables "freshness" to be retained longer for the consumer, and thus increases product appeal (even though some bakers say freezing adversely affects other qualities), and (3) the potential cost reduction possibilities offered by freezing.

3. A study of rice distribution patterns for the 1960-61 and 1961-62 crop years has been carried out to provide basic market data to assist the industry in improving distribution efficiency through more detailed knowledge of markets.

In the 1961-62 marketing year, rice millers and repackagers reported the distribution of 15.8 million hundredweight in the domestic continental market for all uses. This is a gain of 3.3 million hundredweight, or about 26 percent over total distribution for the same uses reported in 1956-57. Excluding use in beer, per capita distribution of milled rice amounted to 7.0 pounds in 1961-62 as compared to 5.8 pounds in 1956-57. A number of States registered gains over the previous period indicating consumption is increasing in areas where little rice has been used. Industry-wide promotional efforts coupled with new product introductions appear to be important factors in expanding the domestic rice market.

4. An evaluation is being made, under contract, of the most promising new market possibilities for starch, the primary problem of product development needed in expansion of industrial markets for cereal grains. So far, four types of materials for possible use by three major industries have been suggested as meriting development and testing research. Starch was proposed as a raw material for: (1) A series of high specific gravity compounds potentially more efficient as solvents than present materials in a number of industrial processes, (2) carbonated as a shrink preventative and preservative for concrete, (3) cationic compounds for use in various chemical processing operations, and frozen for changed gel and paste characteristics with potential usage in selected separation of materials in ore and petroleum refining operations.

B. Merchandising and Promotion

1. Economics of Inventory Control and Ingredient Procurement in Feed Manufacturing. Reduction in cost and improved pricing efficiency for ingredients used in feed manufacturing through development and application of quantitative techniques of managerial decision making are goals of research being conducted in cooperation with the Purdue Agricultural Experiment Station. Preliminary results indicated opportunities for considerable savings in ingredient costs through use of linear programmed least cost formulas which are being tested prior to introduction of variations of the normative assembly model. Tests are being made of the feasibility of forecasting finished sales and ingredient requirements through experimental smoothing.

C. Transportation and Storage

1. Grain Transportation in the Northwest. In the Northwestern States of Montana, Idaho, Utah, Wyoming, Oregon, and Washington, railroads haul most of the grain shipped from country points to processors and to millers, primarily because of the in-transit shipping privileges provided by the railroads. Country operators located at or near river transfer facilities are turning to trucks and barges, or a combination of those carriers. Railroads generally cannot compete effectively with the low cost transportation offered by the truck-barge combination for movements of grain bound to Pacific ports for export.

During the crop year 1960-61 about 40 percent of the trucked grain was hauled by common or contract carriers. Exempt motor carriers moved 32 percent and privately owned or leased trucks carried 26 percent. Itinerant buy-and-sell merchant truckers handled only 2 percent of the grain trucked from country points.

The results of a detailed analysis of the movement of "free" wheat in the State of Washington have been published in speech form.

The Portland port area, including Longview and Vancouver, received the bulk of the rail shipments from country origins in Washington. In 1960-61 the Portland area received 39 percent of the total rail movement of wheat. Twenty-two percent of the rail wheat moved to Puget Sound ports, 24 percent went to the Pasco-Kennewick area, and 11 percent went to Spokane. The remainder was shipped to smaller or unknown markets in the Northwest or to California. Most of the wheat shipped by rail to Pasco-Kennewick is probably reconsigned to be terminated at Columbia River or Puget Sound ports. Probably a portion of the wheat shipped to Spokane continued to the coastal ports. All the rail movement could be considered longhaul movement since the rail cars generally originated at the producing area and terminated at the major coastal markets.

Trucks hauled about 13.9 million bushels or 28 percent of total "free" wheat shipments in Washington during 1960-61. Fifty-two percent of the truck shipments to known destinations moved less than 150 miles, 39 percent was shipped 150-299 miles, and only 9 percent traveled 300 miles or more.

Washington country elevator operators estimated that about 27 percent of their truck shipments of wheat in 1960-61 moved directly from farm storage to terminals or other receivers. This selling method probably saves the farmer money and time since he does not have to deliver the grain to the elevator.

All data for the Northwestern Survey have been gathered and analyzed. The manuscript is nearing completion and should be ready for review during the fourth quarter of calendar year 1963.

2. Grain Transportation in the Southwest. The study of grain transportation in the Southwestern States of Arizona, Colorado, New Mexico, Oklahoma, and Texas will be completed by the end of the calendar year 1963. This study is being done, under contract by Agri Research, Inc., subsidiary of Dunlap and Associates, Stamford, Connecticut. The findings are based on data collected by means of personal interviews with 470 country elevators, terminal elevators, feed manufacturers, and flour mills. The 470 firms interviewed represented about a 20 percent sample of grain handlers in the States covered by the survey.

3. Grain Transportation in the North Central and Southern States. The studies of grain transportation in the North Central and Southern States are cooperative projects with regional grain marketing committees.

Data have been collected in both areas and are being analyzed. Significant changes in grain marketing practices are being found. The relative importance of the various carrier types is changing with truck and barge transportation becoming more important and railroads less so in southbound movements. The changes in the use of the various modes of transportation are causing changes in the location and the use of storage facilities. Storage facilities are tending to be located and expanded either near production areas or processing points.

4. Covered Hopper Cars for Moving Grain by Rail. A study of the feasibility of using covered hopper cars for moving grain is nearing completion. All research data have been assembled and analyzed; a first draft of the manuscript has been reviewed.

It appears that the utilization of covered hopper cars would be very comparable to the present utilization rate of boxcars when in grain service, even with a 100 percent empty car return. The greater capacity of the new lightweight covered hoppers enables carriers to operate them with a per unit cost generally lower than the standard boxcars at comparable utilization rates.

About 40 percent of the country elevators surveyed are equipped to load covered hoppers and over 60 percent of the terminals and processors can load and unload them. Firms presently unable to use covered hoppers indicated their willingness to arrange to do so, within the range of their individual economic capabilities. Judged on the basis of costs of necessary changes in loading and unloading equipment, covered hopper cars seem to be more acceptable than semitrailer trucks as a substitute for standard box-cars in the movement of grain.

D. Product Quality

1. Evaluation of Hay Grading. A completed mail survey shows that (1) Federal hay grades need revision to include chemical tests and moisture determination; (2) chemical and moisture changes of alfalfa during storage are very small, indicating that the change in economic value is also small; and (3) no significant change was found in the number of cores of alfalfa needed to provide a representative sample to be used for chemical analysis.

E. Costs, Margins and Efficiency

1. Marketing Margins and Costs for White Bread. Prices of many processed agricultural products--particularly bread--have continued to rise since World War II. Much of the rise is attributed to increases in cost of processing and distribution. Continued research is needed (1) to determine the magnitude of this rise, and (2) to find means to process and distribute agricultural products more efficiently.

Up-to-date analysis of price spreads for white bread indicate that bread prices continued to rise in 1962 to 21.2 cents per 1-pound loaf of white bread up 0.3 cent over 1961. Major findings in Miscellaneous Publication No. 712 and Marketing Research Report No. 623 were reported last year based on preliminary analyses. The final publications during the current year did not modify the findings reported earlier.

2. Cost and Efficiency in the Rice Milling Industry. The cost of milling rice is a key factor in determining the level of export subsidies for rice and the price supports to farmers for several varieties of rice. Up-to-date information on rice milling cost therefore is essential for a successful operation of public programs in the rice industry. Such information supplemented with cost standards of operation is also useful to management of rice mills to guide them towards greater efficiency of operation.

Progress during the year is indicated by (1) initiating, conducting, and completing a study of rice milling costs at the request of the Agricultural Stabilization and Conservation Service, (2) continuing the analysis and drawing up a draft of a report on labor standards in various phases of

rice mill operations. Findings on rice milling costs were transmitted to the Agricultural Stabilization and Conservation Service in a short confidential report. Preliminary results of the analysis on labor productivity in rice mills suggest that labor is an important cost item in mill operations and that management could improve the efficiency of their plant operations by better utilization of labor resources.

3. Cost and Efficiency in the Elevator Industry in the Spring Wheat Area. The elevator industry in the spring wheat area, geared to pre-World War II marketing patterns, was forced to expand rapidly after the war due to shortened harvest period, increased production, and Government programs.

Expansion has not been orderly. Information is vitally needed by elevator management as to the most efficient use of resources, improvements in operating procedures and the rational allocation of costs among the segments of the enterprise. Progress during the year is indicated by the completion of an economic-engineering study (mainly of labor and power inputs) at 14 elevators. Terminals, sub-terminals, and country elevators were included. Observations were made twice at each elevator, once during the busy season and once during the slack season. Analysis of data is now underway.

4. Cost and Efficiencies in Bread Distribution. The retail price of bread has been rising continuously since World War II. Much of this increase has been attributed to the increase in cost of distribution. A study is underway to determine the cost and efficiencies of alternative methods of bread distribution. Progress under this project during the past year consisted of developing the necessary forms for collecting data for an economic-engineering study, complete the fieldwork, and begin to analyze data.

5. Cost of Operating Grain Elevators. The costs and charges for storing and handling grain in country and terminal elevators materially affects the cost of operation of price-support programs, returns to farmers, and incomes of elevator operators. Accurate up-to-date information on these costs and charges is essential for a successful operation of the price-support programs for grains. All fieldwork covering 45 country and terminal elevators has been completed and data assembled. The extensive field survey included time and motion studies of grain handling operations and personal interviews with management of grain elevator operations.

6. Cost and Efficiency in the Operation of Feed Mixing Plants. Mixed feeds production has increased greatly in recent years. At the same time, production facilities have been decentralized. Feed mill management badly needs information on production standards in various phases of feed mill operation to guide them in reducing costs in old mills and in planning to build new facilities.

A study by Iowa State points out that feed manufacturers have little profit motive for innovating feeder contracts. Although not all programs lost

money for the feed manufacturers, on the average, the programs lost \$.87 per ton.

The report MRR-564 on the labor and capital for mixing feeds has used two models with cost data and standards obtained from survey. An outlay of about \$49,000 would be required to build an 80-ton, 8-hour feed mill. A larger mill with a 200-ton per 8-hour capacity would cost about \$80,000. If the smaller mill operated one shift annually, the operating cost would be about 80 cents per ton. With two shifts, this mill would reduce the annual cost per ton to 70 cents. The larger mill, with a one-shift operation, would produce feed at an annual cost of 63 cents per ton. This mill, operating with two shifts, could reduce the cost per ton to 55 cents. If both mills produced the same amount of mixed feed annually, (52,000 tons), the larger mill would have about a 12 percent cost advantage.

The manuscript on packing mixed feeds also uses two models: One packs 65 tons, and the second packs 160 tons per 8-hour day. It would require 7.951 man-hours for the smaller mill to pack this amount at a cost of 39.3 cents a ton. The larger model takes 14.346 man-hours to package the 160 tons of feed at a cost of 29.8 cents per ton. With both models packing 42,000 tons of mixed feed a year, the larger model would have a 20 percent cost advantage. Both models' costs would increase about 18 percent if their percent of total feed mixed that was packed dropped from 80 to 30 percent.

A manuscript on the receiving cost center operations is now under preparation. Two models with 80 and 200 tons capacities are used in this study. The 80-ton model requires on the average 6.1 man-hours a day to receive 80 tons of incoming ingredients. In the 200-ton mill, 200 tons of incoming ingredients require about 12.97 man-hours per day.

7. Cost and Efficiencies of Commercial Seed Processing Plants. Seed production and processing has expanded greatly, especially in the Northwest as a result of increased demand for cover crops (stimulated by U. S. farm programs). Seed plant operators urgently need objective information on costs and related factors to guide them in expansion plans. A report on "Cost and Efficiency in the Operation of Oregon Commercial Seed Processing Warehouses" is being published. It indicates that the Oregon seed processing industry is dominated by many smaller plants and that the economies of size are not being taken advantage of by the seed processing industry. The report establishes through an economic-engineering method several model plants of different size as a guide to management of seed processing facilities to improve the efficiency of their operation. Different handling methods are analyzed for various types of grass seeds. Given a unique method of handling, a plant processing 1,000 tons of rye grass seed would incur a total operating cost of \$16.96 per ton against \$10.20 per ton for a plant which handles and processes 5,000 tons of rye grass a year.

8. Impact of Grain Banks on Feed Milling and Farming. Little is known about a new merchandising technique in the marketing of feed grains and mixed feeds. This technique, commonly called grain banking, became widespread in recent years in the Midwest. Information on its impact on the operating efficiency of the feed industry is needed to guide farmers and management of feed mixing plants towards more efficient methods of marketing. A grain bank is an arrangement between a local feed mill and a farmer whereby the farmer deposits grain with the mill for temporary storage and withdraws it in the form of mixed feeds. About 1,500 grain bank operators in Ohio, Indiana, Illinois, and Iowa were surveyed. It was found that the grain bank method of distributing feeds can render significant efficiencies country elevator. The use of the grain bank permitted the elevator operator to schedule the feed processed, thereby increasing output by 75 percent with the same facilities and labor. The majority of the grain bank customers used services as: bulk delivery, shelling, drying, grinding, and mixing. However, the use of these services varied with the use of particular feeds as well as between different feeds. Grain banks were the busiest during the winter months and processed the least in the summer. Mill management emphasized the primary reason for starting grain banks was to increase concentrated feed sales. Customers liked the grain bank because of convenience, many services, and lack of storage space needed on the farm.

F. Structures, Practices and Competition

1. Structure of Northeastern Grain Markets. The structure of the Northeastern grain markets has changed rapidly in recent years creating marketing problems for many agencies engaged in handling, processing and distribution of grain and grain products. Research on changes in trends in grain markets in the Northeast is designed to provide the industry with basic data to make optimum adjustment to changing conditions.

Progress during the year is indicated by completing all necessary work to obtain needed data for the analysis. Information obtained through mail surveys and personal interviews is now being tabulated for data processing. Some 1,500 grain handling and processing facilities were covered. No findings are yet available.

2. Storage of Sorghams. The rapid increase in sorghum grain production during the 1950's and government programs changed marketing patterns and required additional storage capacity. Findings show that on-farm storage increased from 9 million bushels in 1953 to 53 million bushels in 1960; about two-thirds of the sorghum grain is sold at harvest in the Coastal Bend due to early season price advantage, while in other areas there is greater tendency to sell at a later date; three-fourths of the farmers in the Coastal Bend who store sorghum also have drying and aeration facilities while less than 10 percent of the farmers in other areas have driers

and aeration equipment. Commercial storage capacity of almost 650 million bushels in 1960 is more than double the 1955 space. Sorghum grain occupies about 75 percent of this space. There is a wide variety of types of storage and methods of storing although both are rapidly becoming standardized.

3. Pricing Forage. There is almost no marketing structure for forage. Lack of pricing in a common market results in inefficient pricing and produces price differentials that have no economic basis. The result is that forage is not moved efficiently. Little or no relationship exists between price and Federal grade, price and protein content, or between price and any of the factors of cutting, seasonality, quantity of hay sold, and type of buyer. Although in general, average prices for U.S. No. 1 alfalfa hay exceeded the prices for U.S. No. 2, U.S. No. 3, or Sample grade alfalfa, the differences were less than expected. In Washington State, one lot of U.S. No. 1 alfalfa sold for \$18 per ton while U.S. No. 2 alfalfa sold for as high as \$28 per ton. Also, in Nevada the average price of U.S. No. 2 alfalfa exceeded the price of U.S. No. 1 alfalfa.

G. Information and Outlook

1. New Grain Market News Study in Missouri.

In cooperation with the University of Missouri a review was made of all marketing information services provided by State and Federal governments in the State. These services were identified as to type and kind; and the publication to be issued indicates sources of each data series and the kinds of information which each series presents so farmers will be able to quickly ascertain what the local price, quality, and product movement situations are for leading Missouri commodities.

The USDA cooperated with the Missouri Department of Agriculture in establishing an experimental grain market news service. This service reported current transactions on interior grain markets.

A mail survey of Missouri farmers and marketing firms receiving this report showed this service was providing local price and grain movement information not elsewhere available. Because of the favorable reception of this reporting service, Missouri Department of Agriculture will continue this service.

PUBLICATIONS REPORTING RESULTS OF U.S.D.A. AND COOPERATIVE RESEARCH

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CONSUMER PREFERENCE AND QUALITY DISCRIMINATION -
HOUSEHOLD & INDUSTRIAL
Standards & Research Division, SRS

Problem. With the increasing complexity of marketing channels and methods, it has become almost impossible for the consumer to express to producers either his pleasure or displeasure with available merchandise. In order to market agricultural products more efficiently, we need to understand existing household, institutional, and industrial markets and the reasons behind consumers' decisions to purchase or not to purchase. Information is needed on preferences, levels of information or misinformation, and satisfactions or dislikes of both present and potential consumers. We also need to know consumer attitudes toward the old and new product forms of agricultural commodities and their competitors, and probable trends in the consumption of farm products. We need to know the relationship between agricultural and nonagricultural products and the relationship of one agricultural commodity to another in consumers' patterns of use. Producer and industry groups and marketing agencies consider this information essential in planning programs to maintain and expand markets for agricultural commodities which, in turn, increase returns to growers.

USDA PROGRAM

The Special Surveys Branch of the Standards and Research Division conducts applied research on representative samples of industrial, institutional, or household consumers and potential consumers, in local, regional, or national marketing areas. Such research may be conducted to determine: Attitudes, preferences, buying practices, and use habits with respect to various agricultural commodities and their specific attributes; the role of competitive products, and acceptance of new or improved products.

The Special Surveys Branch also conducts laboratory and field experiments in sensory discrimination of different qualities of a product. These studies ordinarily relate discrimination to preferences and attitudes as they influence purchases in order to assess the standards of quality, packaging, etc., which are needed to satisfy consumer demands.

In addition to surveys of consumer preferences and discrimination, the Special Surveys Branch also provides consultants and conducts special studies, upon request, for other agencies within the Department of Agriculture or within the Federal Government, when survey methods can be usefully applied to the evaluation of programs, services, or regulatory procedures of interest to the requesting agencies.

The work of the Branch is carried out in cooperation with other Federal governmental agencies, divisions within the Department of Agriculture, State Experiment Stations, Departments of Agriculture, and land grant colleges, agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are usually conducted by the Washington staff, with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology and other social sciences, in Washington, D. C., which is headquarters for all of the survey work whether it is conducted under contract or directly by the Branch.

Work on consumer preference for wheat products involved 0.1 Federal professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Consumer Acceptance of Bulgar. The complete report of results of a market test to determine consumer acceptance of a new canned form of cooked whole wheat (bulgur), developed by the Western Utilization Research and Development Division of the Agricultural Research Service, was published in December 1962. This test, details of which were discussed in a previous progress report, was conducted in Wichita, Kansas, in cooperation with Economic Research Service and the Kansas Wheat Commission.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Umstott, H. D. and Hollon, D. S. 1962. Redi Wheat -- A New Canned Cooked Bulgur. Marketing Research Report No. 574.

ECONOMIC AND STATISTICAL ANALYSIS
Economics and Statistical Analysis Div., ERS

Problem: Adequate and accurate information is needed on supplies, production and consumption of farm products, and the effects these and other factors have on the prices of agricultural commodities. Such information is needed in planning operations for the producers, processors and distributors and also benefits the consumer in selecting his purchases. Similarly accurate quantitative knowledge of the interrelationships among prices, production and consumption of farm products are needed by Congress and the Administrators of farm programs to effectively evaluate current and future price support and production control programs.

Due to the instability of the prices he receives, the farmer stands in special need of accurate appraisals of his economic prospects if he is to plan and carry out his production and marketing activities in an efficient and profitable way. The farmer needs to be provided with economic facts and interpretations comparable to those available to business and industry, through a continuous flow of current outlook intelligence and the development of longer range projections of the economic prospects for the principal agricultural commodities.

USDA PROGRAM

The Department has a continuing program of basic research concerning the factors affecting prices, supply, and consumption of principal agricultural commodities and the analyses of the situation and outlook for selected commodities. The Federal professional man-years involved for grain are 4.5 annually, of which 0.5 are devoted to work on the supply and demand for feed grains and 4.0 to work on the grain situation and outlook. The program is carried on in Washington, D. C.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Demand and Supply Analysis

Work in this area was limited to demand and supply analysis of soybean meal. In the analysis, the quantity of soybean meal demanded for feeding purposes was explained by (1) the price of soybean meal, (2) number of high protein feed consuming animal units, and (3) quantity of cottonseed meal fed. Preliminary results indicated that one percent increase in price results in a 0.7 percent decrease in the quantity demanded for feed. The production of soybean meal is a function of the quantity of soybeans processed. The quantity of soybeans processed was explained by (1) the value of soybean meal and oil relative to the value of an equivalent quantity of soybeans, and (2) the production of soybeans.

B. Situation and Outlook Analysis

1. Food Grains. In the 1963-64 marketing year, the supply of wheat continued the decline of the last several years. This resulted from both special domestic programs to restrict production and intensified programming under Food for Peace and similar export programs. Carryover stocks are expected to be reduced at the end of the season for the third consecutive time. Prices in 1963-64 are expected to average near the price support loan rate as they have in recent years. However, towards the end of the current marketing year, the approaching 1964 crop and its much lower price support rate will have a pronounced effect on the wheat economy.

Supplies of rice continued heavy with large crops in both 1962 and 1963 offsetting smaller beginning stocks. As in the case of wheat, a high level of exports under Food for Peace programs have prevented any appreciable increase in carryover. Prices were above support in 1962-63 although they were somewhat below the high price received the previous year. In 1963-64 prices will probably continue to average above the support level.

During the past year special attention was given to analysis of the wheat certificate program and alternatives to this program. The concept of the certificate program was a sharp departure from that of previous wheat programs and many new problems were encountered. As a result, a considerable amount of detailed analysis was necessary. Much of this work was included in the Department's bulletin Wheat, The Program for 1964 -- An Economic Analysis.

An article published in the April 1963 issue of the Wheat Situation dealt with protein premiums for wheat, and indicated that the variation in prices for different proteins was related to both the absolute and relative quantities available. Additional attention was given to rye in 1962-63. Situation and outlook reporting on this crop was expanded, with additional attention to the impact of world supply and demand on the rye situation in the United States. Several special analyses were prepared of existing or proposed Government programs or actions on food grains. Long-run projections (5 years) were developed as part of a set of ERS projections for the economy as a whole.

2. Feed Grains. Carryover of feed grain was reduced 11 million tons in 1962-63, as acreage was down. This brought stocks down about 24 million tons in the past two years, following a steady increase during the preceding decade. About 25 million acres were diverted to soil conserving use under the Feed Grain Programs in 1961 and 28 million acres in 1962. Also, domestic and export demand continued strong and total disappearance of feed grains rose to record levels in the 2 years. In 1963, participation in the Program was a little greater than in 1962, but farmers diverted a smaller percentage of the base acreage and total feed grain acreage rose

about 3 percent. Although production is a little above last year, it probably will fall short of total utilization, and a further decline in stocks is in prospect for 1963-64.

Because of their importance in the feed supply-utilization balance, major emphasis in the past year has been on analysis of the Feed Grain Programs in operation, and proposed alternative programs. Results of studies of Programs for 1961, 1962, and 1963 have been summarized in the Feed Situation and other reports. Trends in feed grain production, consumption, prices, and price relationships were analyzed and results presented graphically in the November, 1962, issue of the Feed Situation. Feed grain prices proved low in recent years in relation to both livestock products and other inputs in livestock production. Low feed prices were accompanied by a substantial increase in the rate of feeding per animal unit from 1956 to 1960, then relative stability in the rate. During 1962-63 prices of feed grains rose in relation to livestock, and feeding ratios are generally less favorable than during the period 1958-61.

Special studies were prepared on longer term trends and seasonal variation in supplies, consumption, and prices of fish meal and alfalfa meal. These revealed upward trends in recent years in both supplies of and demand for these specialized feeds. They also showed pronounced seasonal variation in production and more moderate seasonal variation in prices. High-protein feeds continued to receive special attention as strong domestic and foreign demand pushed soybean prices to the highest level since 1953-54 despite increasing supplies. In connection with a set of ERS projections for major commodities, analyses were made of probable trends in feed grain supply, utilization, prices, and cash receipts (the next 5 years) under two types of programs and under "free market" conditions. The study indicates that under "free market" conditions prices would decline materially from present levels to move the larger feed grain production into consumption.

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